A1250-1
11/4/87

NOVEMBER 2, 1987

CHEMICAL & ENGINEERING

NEWS

051111 79C098 9 K AR65444SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

ANTARCTIC OZONE HOLE

Latest expedition reveals
unexpected complexity
Page 22

Volume 65, Number 44
CENEAR 65 (44) 1–56
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

NOVEMBER 2, 1987

News of the Week

- **Federal R&D budgets for fiscal 1988 are in peril from hurried efforts to reduce the federal deficit. Page 4**
- **One of longest jury trials in history ends with $16 million punishment for Monsanto stemming from 1979 spill containing trace of dioxin. Page 5**
- **Success with genetically altered mice that produce human protein eventually may lead to low-cost method of harvesting many important substances. Page 5**
- **Chemical firms don't seem particularly worried by recent stock market plunge, although stock value of 10 chemical firms has fallen 26% since mid-October. Page 6**

Cover: Computer-generated map depicts satellite measurements of ozone above southern hemisphere on Sept. 27, 1987. At center of map is South Pole; Antarctica is outlined in white. Darkest colors at center represent unprecedented low levels of ozone in ozone hole. Photo courtesy of NASA

Letters 2

Concentrates

Business 7
Government 16
Science/Technology 21

The Departments

Books 31
ACS Focus 36
Meetings 54
Newscripts 56

Business

Chlor-alkali producers expand capacity, mostly through debottlenecking, to ease tight supplies and to meet strengthening demand. **Page 13**

Reinforced plastics use is projected to grow at an accelerated rate through the rest of the 1980s in a new Freedonia Group study. **Page 15**

Government

Occupational disease notification bill passed by House last month now goes to the Senate where it faces strong opposition. **Page 19**

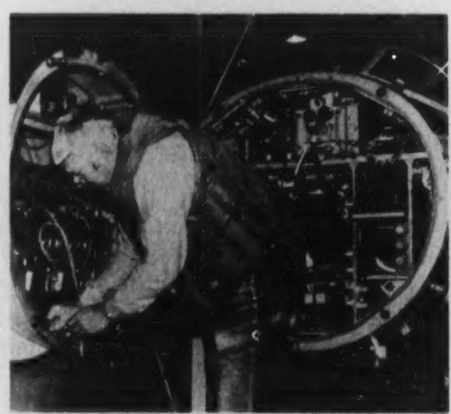
Law that controls pesticide use in the U.S. does not protect health of users of home pesticide products, says Consumers Union. **Page 20**

Technology

USI Chemicals' facilities expansion more than doubles its polymer product R&D capabilities; EniChem enlarges its dimethyl carbonate-producing volume; Akzo has quaternary ammonium salts available as phase-transfer catalysts; new database eases information-gathering on federal regulations for chemical substances. **Page 27**

Awards

ACS award winners: Clark, Chisholm, de Gennes, Doyle, Escudero, Field, Fisher, Fox, Gardner, and Goddard. **Page 37**



Science

Preliminary data from NASA expedition suggest that both chlorine photochemistry and meteorological conditions contribute to seasonal Antarctic ozone hole phenomenon. Page 22

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Wilbert C. Lepkowski, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Joyce A. Richards (Head), Anne Riesberg (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve
© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

S.O.S. for chemists

SIR: The letter by Peter A. Reinhardt (C&EN, Sept. 7, page 4) citing the need for chemists to participate in the management of local chemical risks could not be more timely. Recently, the southbound section of the major freeway in San Diego was shut down for eight hours because a bag of iron oxide was spilled on the highway. The cleanup crew interpreted their Material Data Safety Sheets as classifying iron oxide as a toxic and hazardous substance. A member of the crew was quoted as saying that all powdered materials when mixed with air presented an explosive problem. A second crew member claimed skin blistering from handling the iron oxide. Apparently, not even a rudimentary knowledge of basic chemistry is required of crews charged with cleaning up chemical spills. One wonders how a really serious toxic spill would have been handled.

I suspect that this comedy of errors was not an isolated occurrence and that most communities are not better equiped to handle chemical hazards in a more intelligent manner. A major highway in the state of Washington was recently closed down for several hours because a bag of flour was scattered over the highway. To be fair, in the latter case, the cleanup crew did not know they were dealing with ordinary flour. The crew in San Diego justified their action by saying they had nowhere to turn to for advice on how to handle iron oxide. It would seem that chemists could be of help in their communities on such matters, even if only to the extent of making their telephone numbers available.

Harry Heller
Escondido, Calif.

Professional image

SIR: The remarks made by Jerry R. Mohrig from Carleton College (C&EN, Sept. 28, page 24) are arrogant and condescending as well as an insult to the tens of thousands of B.S. and M.S. chemists. According to Mohrig, all these B.S. and M.S. chemists are amateurs and mavericks, since they do not have a Ph.D. in their curriculum vitae.

However, I am glad to note that in the same issue an application form for membership in ACS asks: "Mr., Mrs., Ms., Miss, or Dr.?" as the means of address. It is therefore obvious that our professional organization does recognize the value and the professional contributions made by these maverick, amateur chemists.

What does Mohrig tell those students at Carleton College who do not complete a Ph.D. program? According to his own words these young men and women are mavericks if they enter the world as chemists.

This attitude is divisive and does not help the image of the profession in the world at large.

Horst Kehl
Lafayette, La.

Descend from Olympus

SIR: I have often thought of commenting on letters published in your magazine, but H. O. Ranger's letter, "Is lab regulation necessary?" (C&EN, Aug. 3, page 2) is the first to actually compel me to act. In it, the writer denigrates the need for lab regulation, stating that although compliance with regulatory standards may be reassuring "it will not save the life or increase the longevity of even the most naive and careless laboratory worker."

Ranger describes the "typical" chemical laboratory as a cross between Shangri-la and Utopia, a magical kingdom presided over by an omnipotent graduate chemist who not only has an "in-depth knowledge" of the "3000 to 5000 bottles of chemicals" surrounding him or her, but has the keen ability to train eager technicians, keep a watchful eye on careless ones, and is blessed with the divine wisdom of knowing when a person has reached the limit and should be reassigned to another, less-hazardous job. On top of all this, this paternal (or maternal) chemist must also have time to conduct meaningful research, keep current in his or her technological field, and, most important, keep abreast of new discoveries in the safety field.

If Ranger is that type of chemist, I extend my congratulations to him. Such people are hard to find. In fact, until recently most lived on a mountain in Greece known as Olympus. Being involved intimately in the chemical safety field for more than a decade, both in the laboratory and as a consultant, I can assure Ranger that few of these persons are working in laboratories today; most chemists are mere mortals trying to achieve Ranger's ideal, but often falling short. How many of us have never been careless or have never given our technicians incomplete, or even improper, in-must be carefully nurtured in huge bioreactors.

"We want to replace the bioreactor with living animals," says Alan Smith, vice president and scientific director of Integrated Genetics. He points out that the transgenic mice produce grams of t-PA per liter of milk, whereas a typical bioreactor's output is in the range of milligrams per liter. In addition, the scientists think it would be cheaper to raise animals than to cater to notoriously temperamental cells in fermentation tanks.

Other commercially important substances might also be produced in the milk of transgenic animals. "We expect virtually any human protein could be expressed," says Katherine Gordon, head of Integrated Genetics' transgenic program. Key candidates in addition to t-PA include Factors VIII and IX, which are used to treat hemophiliacs, and certain industrially useful enzymes, she says. The firm estimates the market for such proteins to be in the billion-dollar range.

Transgenic animals, first produced seven years ago, are created by injecting genes from other species into single-cell embryos. The foreign DNA fuses with the animal's native DNA and is carried into every cell as the embryo grows and divides. Future generations of the animal inherit the foreign gene.

Although the gene for making human t-PA is present in all of the cells of the transgenic mice, the protein is only synthesized in the mammary gland. The researchers dictated where the t-PA would be made by fusing genes that normally control the production of mouse milk whey proteins to the gene for t-PA.

Getting milk from a mouse is not simple, so Integrated Genetics plans to produce transgenic cows, sheep, or goats that secrete human proteins in their milk. Because the biochemistry of milk from dairy animals is so well understood, use of these animals won't require major new studies, says Lothar Hennighousen of the National Institute of Diabetes & Digestive & Kidney Diseases. "A conservative estimate would be that we could make the world's supply of t-PA from a herd of 100 cows," Gordon says. ☐

Chemical stocks still ride Wall Street seesaw

For the second week in a row,-the stock market continued its seesaw pattern last week, although the Dow Jones Industrial Average remained above its Oct. 19 low of 1738. Of the broader composite and industrial market indexes, most showed some recovery, if not stability. Only the American Stock Exchange Index and the over-the-counter indexes descended below their low closing values of Oct. 19.

This isn't to say that stocks aren't hurting. A group of 10 chemical company stocks followed by C&EN lost about 26% of their combined stock market value between Oct. 16, the last trading day before Black Monday, and Oct. 28. Other chemical-related groups did not fare so badly. For a group of five oil companies with chemical production facilities, the total market value fell only 11%. The stock value for a sampling of five pharmaceutical firms dropped 13%, and for a group of five diversified companies with large chemical interests the decline was 15%. Only the highly speculative biotechnology firms did worse than chemical companies; a group of five such firms lost 34% of their market value during the period.

Chemical firms don't seem particularly worried by the downturn in the market, with most downplaying it by pointing out that their stocks are a good buy right now. In fact, at one firm visited by C&EN, the talk among executives was more of what stocks to buy for their personal portfolios than of the detrimental effect that their company's stock drop will have.

Chemical executives are pretty uniform in saying that the downturn will have very little effect on the traditional chemical industry. Most companies are keeping capital spending in check by retrofitting and debottlenecking existing plants to the point that many of the capital expansions they will be undertaking can be financed internally. Thus there is no need for them to go to the equity or debt markets.

The chief fear on Wall Street seems to be that the drop in the market may signal a recession. However, quick surveys by a number of organizations show little or no change in consumer confidence. Thus, economists see little reason to change their forecasts for growth over the next 12 months. There may be some slowdown in new car purchases and in housing construction, but these were already under way, with auto sales down about 10% from year-earlier levels. Other consumer demand probably will hold up, the economists say. ☐

Market value of chemical stocks has fallen precipitously

$ Millions	Stock market value Oct. 16	 Oct. 28	% change
Air Products	$2,530	$1,776	−29.8%
American Cyanamid	3,801	3,332	−12.3
Aristech	782	507	−35.2
Dow Chemical	16,914	12,685	−25.0
Ethyl	2,735	2,032	−25.7
W. R. Grace	2,513	1,697	−32.5
Hercules	3,128	2,504	−19.9
Monsanto	6,773	4,737	−30.1
Olin	1,147	763	−33.5
Union Carbide	3,581	2,457	−31.4
TOTAL TEN CHEMICAL FIRMS	$43,904	$32,480	−26.0%
FIVE OIL COMPANIES	$124,845	$111,393	−10.8%
FIVE DRUG COMPANIES	$62,208	$54,166	−12.9%
FIVE DIVERSIFIED COMPANIES	$37,258	$31,734	−14.8%
FIVE BIOTECHNOLOGY COMPANIES	$5,060	$3,312	−34.4%

Chlor-Alkali Capacity Use Hits Record High for Decade

First major plant expansion in several years signals efforts of producers to ease tight supplies and to meet renewed growth in demand

Bruce F. Greek, C&EN Houston

Near Niagara Falls, N.Y., next month, a joint venture of Olin and Du Pont—Niachlor—will start up an electrolysis plant to make about 660 tons per day each of chlorine and sodium hydroxide (caustic soda). The plant will be a major capacity expansion, the first in several years for the chlor-alkali industry.

Other capacity for the chlor-alkalies has been expanded slightly this year through debottlenecking programs. Producers have been prompted to operate plants very close to capacity for a year or so in the face of strengthening demand and forecasts for demand to remain strong.

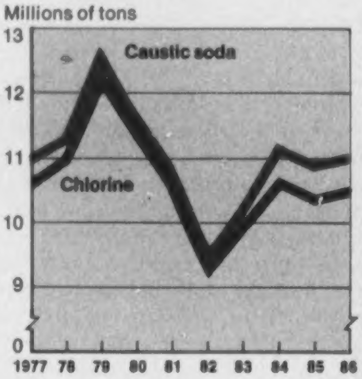
The Niachlor plant will add very little to 1987 available capacity but will be fully available in 1988 along with capacity from other expansions slated to be completed next year. For example, Dow Chemical has begun an extensive debottlenecking program at some of its plants at Freeport, Tex., that will add 550 tons per day of chlorine capacity in increments through the second quarter of 1988. Occidental Chemical also is working to restart (during the second quarter of 1988) a chlorine-caustic plant at Corpus Christi, Tex., which it acquired from Du Pont this fall.

The Niachlor plant capacity and the effect of debottlenecking efforts by Dow and other chlorine producers (as well as the capacity of plants mothballed or temporarily shut down) will provide U.S. capacity of more than 36,000 tons per day of chlorine, or about 13 million tons per year, by next January. U.S. daily capacity has not exceeded 36,000 tons since July 1986, according to the monthly report of the Chlorine Institute, the chlor-alkali industry's trade association. The Chlorine Institute estimates that, as of August this year, 4150 tons per day of chlorine capacity was either mothballed or temporarily shut down.

Production of chlorine in 1987 likely will total about 10.9 million tons, up about 3% from last year. Caustic soda production as usual will be 4 to 5% higher than chlorine production, or 11.4 million tons this year.

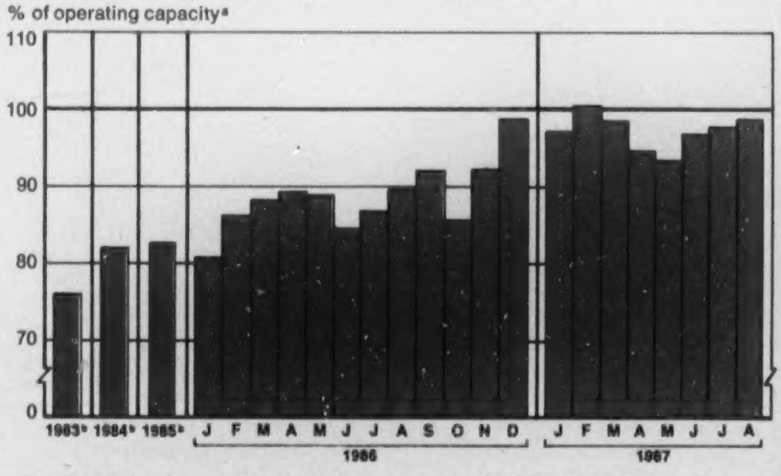
Operable chlorine capacity, estimated by the Chlorine Institute to be more than 35,250 tons per day in August, remains below its historical highs of more than 40,000 tons per day during some months in 1982. In 1982 and other years between 1980 and 1985, plant operating rates fell to low levels—70 to 80% of operating capacity—well below the traditional level of about 95%.

Chlorine, caustic output remains below record high



Sources: Chlorine Institute, Department of Commerce

Plant operating rates reach effective capacity



a Operating rate based on production from all units in operation. b Average of estimated monthly effective rates. Sources: Chlorine Institute, C&EN estimates

To solve the problem of excess

capacity and the costly low operating rates, producers adopted a program of scrapping many older units. Last month in a presentation to the Mexican chemical industry association (ANIQ), Frank H. Romanelli, executive vice president of Occidental Chemical, estimated that 20 U.S. chlorine plants with a capacity of 8700 tons per day were closed in the 1980s by 17 different companies. He pointed out that that amount of capacity exceeds Occidental's current capacity, which is now second largest in the industry. Part of the capacity reduction was offset by minor capacity additions through process and technology improvements.

Most of the plants that have been shut down had relatively small capacities, 435 tons per day on average. Some of those small plants were operated by companies that had a captive use for the products, such as in pulp and paper manufacturing. Energy costs began climbing in the 1970s, making small units less and less competitive and shifting the make-versus-buy option toward buying chlor-alkalies. Few of the small plants are still operating, and industry sources expect them to be shut down as large-volume producers continue to improve their technology and cut their production costs significantly.

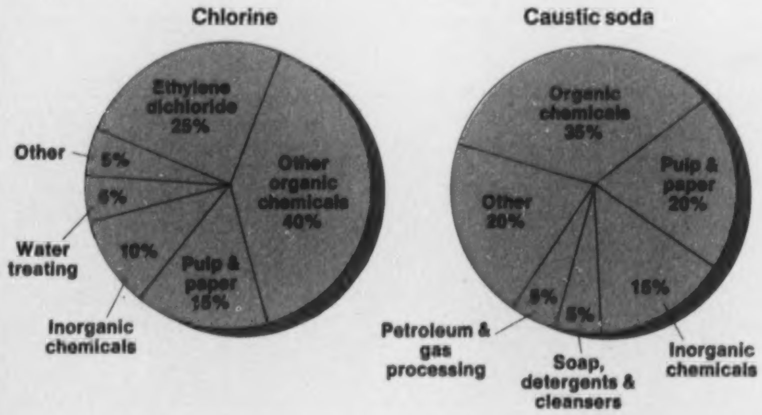
Following several of the plant shutdowns, demand for both chlorine and soda began to improve markedly in late 1985. And now operating capacity is running at about the traditional level of above 95%. Operations in February of this year, for instance, were 100.5% of the then-operating capacity of 35,150 tons per day, the Chlorine Institute estimates. In August, the rate was 98.5% of some 35,250 tons per day of operating capacity.

The strong demand for chlor-alkalies and the capacity reductions have triggered a series of increases in their off-list prices this year. List prices remain about $200 per ton for either chlorine or caustic soda. During the past year, selling prices have moved up to $150 per ton from as low as $100 per ton. If the economy holds, prices will remain firm, according to industry sources.

Longer term demand for chlorine is forecast to grow 1 to 2% annually, for caustic soda 1 to 3%. The wider range forecast for growth in caustic use results from the uncertainties in the export market for caustic. With relatively small capacity increases expected, plants likely will operate at about present levels in 1988 to meet the small demand increase.

Most of the growth in consumption of chlorine will stem from what is currently its fastest-growing use—in the production of ethylene dichloride, a precursor for polyvinyl chloride. This use accounts for nearly 25% of U.S. chlorine consumption and is growing at about three times the rate of total chlorine consumption. U.S. PVC demand is sensitive to the economy because such a large share eventually goes into housing and commercial construction. Demand for PVC in pipe is increasing with the increasing use of large-diameter pipe (which consumes much larger quantities of resin per foot) in sewer systems.

Chlorine and caustic soda have diverse uses



1986 consumption = 10.8 million tons[a]

1986 consumption = 10.3 million tons[b]

[a] Includes net imports of 250,000 tons. [b] Excludes net exports of 600,000 tons.

Other markets for chlorine are growing more slowly. Chlorine use in making inorganic chemicals may rise 1 to 2% annually, pushed by demand for making titanium dioxide. Use in manufacture of organic chemicals may decline slightly because of lower demand for chlorinated organic solvents. Applications in water treatment will grow slowly, as will use in pulp and paper making where competition from other bleaching materials remains strong.

Growth in the use of caustic soda, although stronger than for chlorine, still depends heavily on exports. Exports this year are expected to remain about 1.3 million tons. Net exports likely will decline, however, because of rising imports. Strong U.S. demand for caustic for making pulp and paper and organic chemicals, as well as many small miscellaneous uses, appears to be absorbing imported caustic.

Caustic will continue to face competition from soda ash (sodium carbonate), according to Roger E. Shamel, president of Consulting Resources of Lexington, Mass. As selling prices of caustic rise, consumers with plants that can use either caustic or soda ash for sodium oxide values will shift toward use of soda ash. Recent price increases for soda ash stem from strong export demand and currently make the likelihood of much of a shift slim.

If demand for chlorine and caustic soda continues strong in 1988, as now is expected, this segment of the chemical industry likely will have another good year of production at high levels. Uncertainty of the availability of mothballed capacity, which is more than 10% of operating capacity, has put a damper on plans to add capacity other than through process debottlenecking. □

Reinforced plastics use to pick up momentum

Use of reinforced plastics will grow faster through the rest of this decade than it did in the 1977–86 period, according to a new study by the Freedonia Group, the Cleveland, Ohio-based market research firm.

The study indicates that reinforced plastics demand in the U.S. will increase 5.5% per year to reach 3.2 billion lb in 1991. At that time they will make up about 5.4% of all plastics demand, compared with 5.0% in 1986. By 1995, demand for reinforced plastics will grow to 3.9 billion lb and make up 5.7% of all plastic use. The percentage, however, is still below the 5.8% of all plastics demand posted in 1977.

Reinforced thermoplastics demand will grow about three times as fast by 1991 as that for reinforced thermosets, according to the 105-page study. The study projects demand for thermosets to grow 3.7% per year between 1986 and 1991 to reach 2.3 billion lb, and thermoplastic demand will rise at an average annual rate of 11.1% per year to 900 million lb.

Thermoplastics are the fastest growing segment as a result of their freedom of design, reprocessing abilities, and improved processing techniques, the company says. New developments in blending and compounding, combined with technological advances, will raise demand for reinforced thermoplastics. Nylon and polypropylene are the dominant resins among the thermoplastics, but thermoplastic polyester will be the fastest growing at an annual rate of 16.4%, according to the study.

Among markets for reinforced plastics, increased use of sheer molding compounds is anticipated despite major cutbacks in plastic car body programs by major auto makers. The greatest opportunities will lie in exterior body panels, bumpers, and underhood parts.

Freedonia Group sees the aircraft and aerospace industries as the most rapidly growing market outlet for reinforced plastics, although use in those industries is currently still small. Construction will remain a large market because of cost and performance advantages over competing materials.

Growth in demand for reinforcement materials also will be about 5.5% through 1991. Glass fiber will maintain its dominance, accounting for about 93% of reinforcement materials use. Carbon and other high-performance reinforcing materials will experience the most growth, as the market for advanced composites expands.

Copies of the report can be obtained from Freedonia Group, 2940 Noble Rd., Suite 200, Cleveland, Ohio, 44121, at a cost of $1600.

William Storck, New York

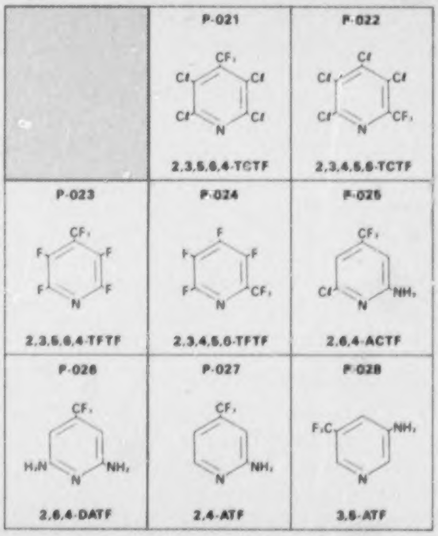
Reinforced plastics demand will hit 3.9 billion lb by 1995

Millions of lb	1977	1986	1991	1995	% annual change 1977–86	% annual change 1986–91
Reinforced thermosets	**1619**	**1914**	**2300**	**2600**	**1.9%**	**3.7%**
Polyester	1539	1781	2136	2410	1.6	3.7
Epoxy	45	69	85	100	4.9	4.3
Other	35	64	79	90	6.9	4.3
Reinforced thermoplastics	**191**	**532**	**900**	**1300**	**12.1**	**11.1**
Nylon	38	146	210	265	16.1	7.5
Polypropylene	68	142	243	370	8.5	11.3
Polyester	34	117	250	385	14.7	16.4
Styrenics	30	49	72	97	5.6	8.0
Polycarbonate	—	45	82	130	—	12.8
Other	21	33	43	53	5.2	5.4
TOTAL	**1810**	**2446**	**3200**	**3900**	**3.4%**	**5.5%**

Source: Freedonia Group

Organic Intermediates through Ishihara Sangyo's Advanced Technology:

NEW PYRIDINE DERIVATIVES



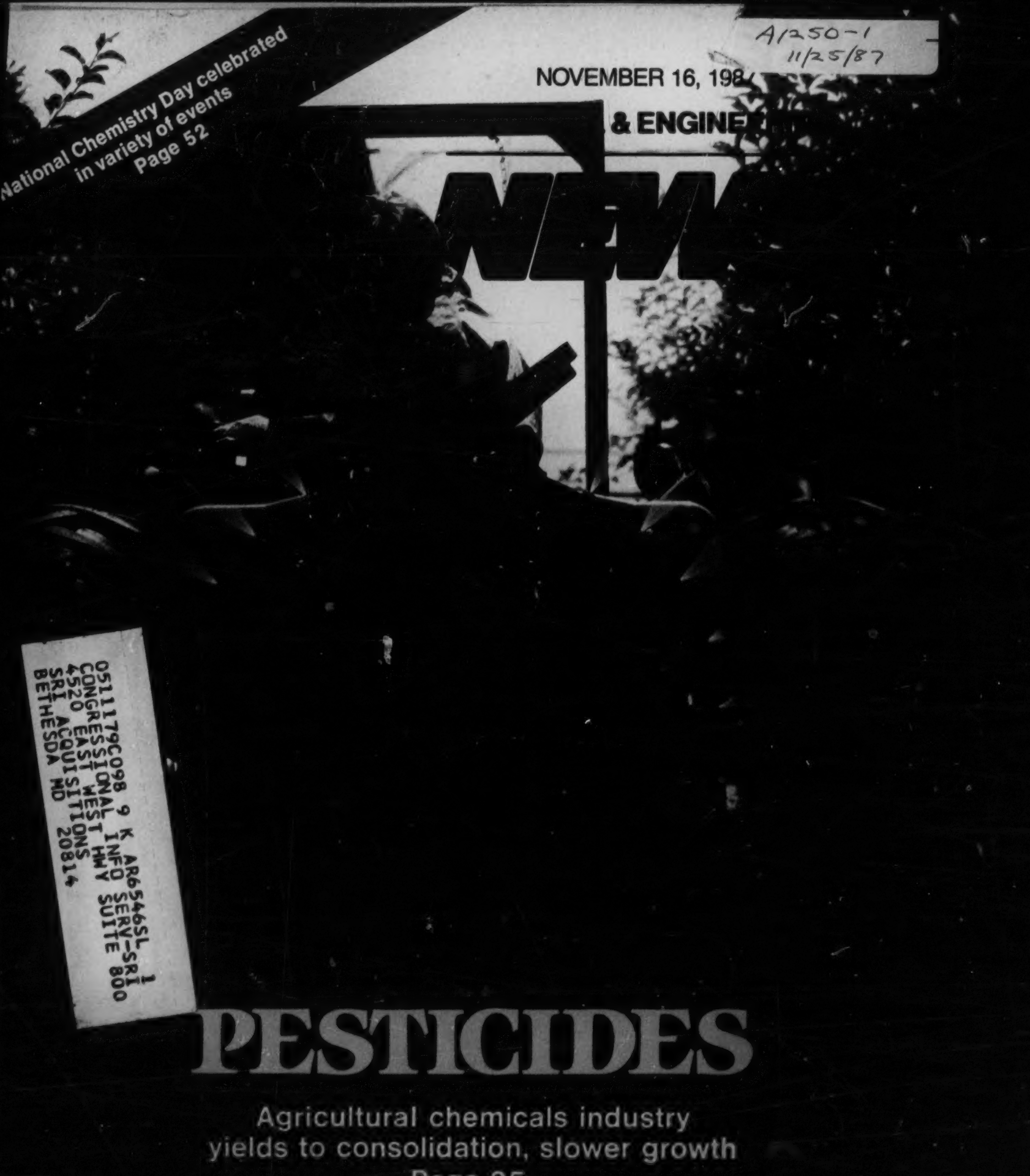
ISHIHARA SANGYO has added the above new compounds to its product line. Although these new developmental compounds are only in the research stage, small samples can be prepared for research and development purposes. We wish to make the best use of our processes to assist in the synthesis of your products.

ISK
ISHIHARA SANGYO KAISHA, LTD.
10-30, Fujimi 2-Chome, Chiyoda-ku, Tokyo, Japan, Telex 2324306 ISK J
ISK (EUROPE) S.A. 33/31 Rue Montoyer, Box 8 1040 Bruxelles
Tel:(02)512-54-50·512-72-78 Telex:23362 ITDD B
ISHIHARA CORPORATION (U.S.A.) Transamerica Pyramid 42nd Floor 600 Montgomery Street, San Francisco, Ca. 94111
Tel:415-421-8207 Telex:278010 ICUSA UR

A1250-1
11/25/87

NOVEMBER 16, 198
& ENGINE
NEW

National Chemistry Day celebrated in variety of events
Page 52



0511179C098 9 K AR6546SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

PESTICIDES

Agricultural chemicals industry yields to consolidation, slower growth
Page 35

Volume 65, Number 46
CENEAR 65 (46) 1–88
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

NOVEMBER 16, 1987

News of the Week

■ **U.S. and Japan move toward a new pact on science exchanges, giving stronger coordinating role to the Office of Science and Technology Policy. Page 4**

■ **Soviet chemical warfare experts are scheduled to tour a U.S. chemical arms facility in Utah later this week. Page 5**

■ **EPA orders Texas Eastern Transmission Corp. to clean up 89 sites along 10,000-mile natural gas pipeline that were contaminated by polychlorinated biphenyls, imposes $15 million fine. Page 5**

■ **Federal agencies charged with protecting public from chemical hazards are failing to systematically regulate carcinogenic chemicals, says an OTA report. Page 5**

■ **Mobay acquires Houston-based Denka Chemical, expanding its U.S. foam cushion business and maleic anhydride operations. Page 6**

■ **The Center for History of Chemistry receives a $2 million challenge grant from the Arnold and Mabel Beckman Foundation. Page 6**

Cover: Apple orchard being sprayed with pesticide. Photo by Mellott/Uniphoto Picture Agency

Letters 2

Concentrates
Business 7
Government 17
Science/Technology 20

The Departments
Books 47
New Products 62
Newscripts 88

Business

Major chemical companies' earnings increased 58% in the third-quarter, but certain markets declined. **Page 10**

Government

Proposed right-to-know trade secret rule delineates criteria to be used in "up front" claims of chemical confidentiality. **Page 18**

Science

Shorter, less technical version of Pimentel Report is aimed at high school students, college nonscience majors, and their teachers. **Page 28**

Pacific basin groups form polymer federation to advance and benefit polymer science and technology. **Page 30**

ACS News

National Chemistry Day was marked by public exhibits, workshops, tours, demonstrations, and variety of other events. **Page 52**

Awards

ACS winners: Marcus, Rabo, Robins, Slichter, Smith, Turro, Wender, Winans, and Wrighton. **Page 71**

Product Report

Agricultural pesticides industry experiences slowed growth as a result of persisting surpluses, reduction of planted acreage, increased environmental and safety awareness, and cost-cutting practices by farmers. Page 35

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Wilbert C. Lepkowski, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Joyce A. Richards (Head), Anne Riesberg (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production / Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeid, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve

© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 87)

LETTERS

Chemical misnomer

SIR: As I have maintained for quite some years, the American Chemical Society is a misnomer and a disadvantageous one.

Ours is a scientific society concerned with the progress of the science of chemistry—not just with compounds and commodities. As such, it would be much more accurately called the American Chemistry Society.

With the launching of National Chemistry Day (it would have been absurd to call it National Chemical Day) perhaps my recommendation will win serious consideration by ACS officers.

As it stands, the term American Chemical Society is, to my mind, woefully inaccurate, a misnomer, and an anachronism.

Alec Jordan
Guilford, N.H.

Women in chemistry

SIR: Thank you for noting in your editorial (C&EN, Sept. 14, page 3) that Jacqueline Barton was honored with the 1988 ACS Award in Pure Chemistry. Not only is this just the second time a woman has received an ACS award for pure research, but it is also the first year in which women have won three ACS awards. Marjorie Gardner received the award in Chemical Education and Marye Anne Fox won the Garvan Medal. Although they have not captured research awards, the Garvan medalists have made important contributions to chemical research, applied fields, and education.

In the past 10 years, the percentage of women obtaining degrees in chemistry has indeed increased substantially. Most of this increase, however, has been due to growth in the number of women attending college rather than to an increasing preference for science among young women. In the past few years the number of women obtaining degrees in chemistry has been steady, and the observed percentage increase is attributable to a decline in the number of men entering the field.

The problem of attracting young people to the pursuit of chemistry is general. Apparently we have not been successful in convincing higher proportions of women, blacks, or Hispanics that science is an exciting, meaningful, and satisfying pursuit. Indeed, we have not competed effectively with other disciplines in attracting young men.

The Women Chemists Committee is compiling suggestions for ways ACS can encourage women to enter and persist in chemistry. We hope that many of the ideas will be helpful to other minority groups and to young people generally. If you have suggestions we should consider, please send them to the Women Chemists Committee, ACS headquarters.

Margaret A. Cavanaugh
Chairman, Women Chemists Committee
Saint Mary's College
Notre Dame, Ind.

Biological detectors

SIR: The article by Pamela S. Zurer, "GC Technique Quantitates Odor-Active Substances in Food" (C&EN, Sept. 28, page 21), describing the "charm analysis" techniques used at Cornell University's department of food science and technology, illustrates the progress made in the use of biological objects as detectors for gas chromatography.

The earliest reported use of biological objects as detectors for gas chromatography was in the late 1950s or early 1960s. In that work the researchers chromatographed extracts of female moths and placed a male moth in the effluent stream from the column. As components of the extract were eluted from the column, those that were sexual attractants caused the male moth to exhibit varying degrees of arousal depending on the activity and concentration. Those components could be diverted to a trap for collection and subsequent identification.

It appears that in the intervening 25 years, the major improvement has been the use of a more sophisticated biological object, capable, when assisted by a computer, of providing more channels of information.

William B. Prescott
Bound Brook, N.J.

Notice to members wishing to resign

ACS members who wish to resign their membership at the end of 1987 should do so now by letter to the ACS executive director. Bylaws specify that anyone who fails to resign by Dec. 31 will be carried on the rolls in 1988 as a member and will be responsible for dues. Failure to pay dues does not constitute a resignation.

Chemical Earnings Continue Strong Showing in Third Quarter

Marc S. Reisch, C&EN New York

Earnings of major U.S. chemical companies continued their strong growth in the third quarter, averaging 58% higher than the year-earlier period. The quarter just may have capped a string of year-to-year gains for major chemical firms as well as the major diversified companies that produce chemicals.

Even as chemical producers and oil firms charted by C&EN were putting together their rosy sales and earnings reports for shareholders, the Dow Jones Industrial Average dropped 508 points. What this may portend for 1988 is, at the very least, difficult to say.

The Dow Jones drop aside, the chemical industry registered a superb quarter. The 58% increase in earnings from the third quarter of 1986 the major chemical companies surveyed by C&EN came on a 17% growth in sales. Together they indicate that efficiency steps plus improved capacity utilization in many areas, notably plastics and even some basic chemicals, provided plenty of earnings leverage. Average profit margins slipped only slightly from 7.0% in the second quarter of this year.

Still, certain major chemical markets—specifically agriculture, construction, and automobiles—continue to sag. In agriculture, an overabundance of basic raw materials for the production of fertilizer has forced continuing industry realignment and prices continue to

Chemical industry leaders for the third quarter . . .

Sales

Rank 1987		$ Millions	Rank 1986
1	Dow Chemical	$3357.0	1
2	Monsanto	1902.0	2
3	Union Carbide	1730.0	3
4	W. R. Grace	1100.6	5
5	American Cyanamid	1039.0	4
6	Hercules	653.9	6
7	National Distillers	617.2	12
8	B. F. Goodrich	564.0	7
9	Air Products	543.6	8
10	Rohm & Haas	540.9	9

Earnings[a]

	$ Millions	Rank 1986
Dow Chemical	$330.0	1
Monsanto	100.0	2
Union Carbide	74.0	6
American Cyanamid	54.7	5
Freeport-McMoRan	53.9	13
Hercules	50.3	3
Ethyl Corp.	46.3	4
W. R. Grace	41.0	16
Rohm & Haas	39.3	7
Air Products	39.1	8

Profitability

	Earnings as % of sales	Rank 1986
Freeport-McMoRan	20.5%	3
Georgia Gulf	15.8	13
International Flavors	14.5	1
Vista Chemical	10.8	11
Betz Laboratories	10.8	4
Ethyl Corp.	10.5	2
Dow Chemical	9.8	14
Loctite	9.4	6
Nalco Chemical	9.4	5
Aristech	7.8	8

. . . and for the first nine months of 1987

Sales

Rank 1987		$ Millions	Rank 1986
1	Dow Chemical	$6851.0	1
2	Monsanto	5793.0	2
3	Union Carbide	5069.0	3
4	W. R. Grace	3210.6	5
5	American Cyanamid	3140.8	4
6	Air Products	2132.2	8
7	Hercules	2006.3	7
8	National Distillers	1824.5	11
9	Rohm & Haas	1671.3	9
10	B. F. Goodrich	1600.7	6

Earnings[a]

	$ Millions	Rank 1986
Dow Chemical	$891.0	1
Monsanto	392.0	2
Union Carbide	209.0	8
American Cyanamid	203.8	5
Freeport-McMoRan	190.1	4
Air Products	159.7	6
Hercules	158.9	3
Rohm & Haas	158.8	9
Ethyl Corp.	140.4	7
W. R. Grace	88.6	20

Profitability

	Earnings as % of sales	Rank 1986
Freeport-McMoRan	23.9%	1
International Flavors	15.1	2
Dow Chemical	13.0	6
Ethyl Corp.	11.2	3
Georgia Gulf	11.2	14
Betz Laboratories	10.7	4
Loctite	9.7	7
Nalco Chemical	9.5	8
Rohm & Haas	9.5	11
Vista Chemical	8.0	16

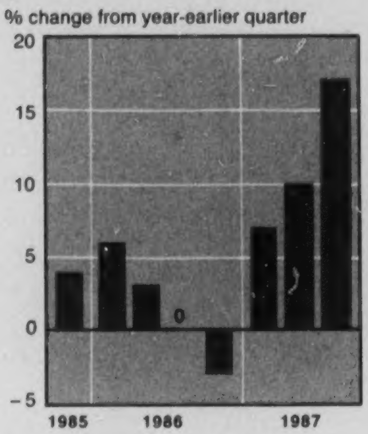
Note: For 30 chemical companies listed on page 12. [a] After taxes

Chemical industry 1987 third-quarter results

- **Sales increased 17%**
- **Earnings jumped 58%**
- **Profit margins at 6.9%**
- **Production rose 7.4%**
- **Prices moved up 5.4%**

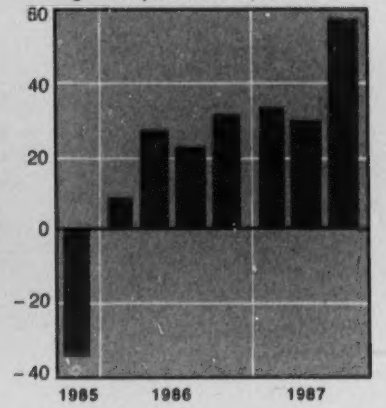
Sales

% change from year-earlier quarter



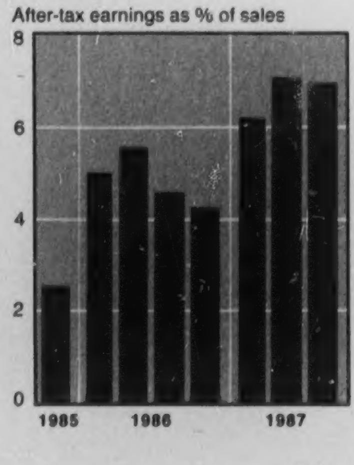
Earnings

% change from year-earlier quarter



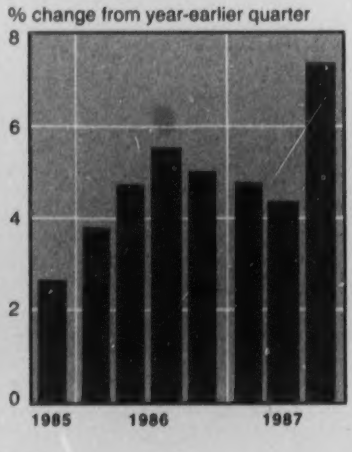
Profit margins

After-tax earnings as % of sales



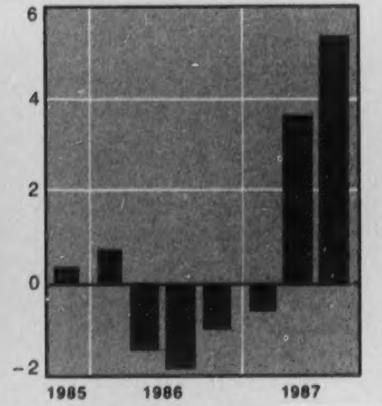
Production

% change from year-earlier quarter



Prices

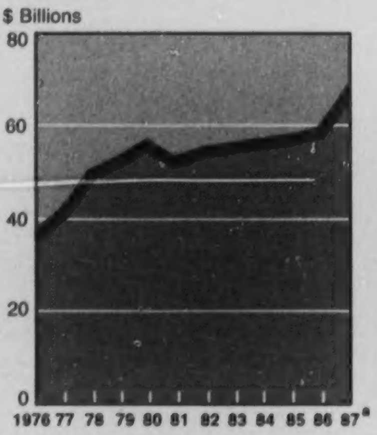
% change from year-earlier quarter



Sales this year will increase about 12% and earnings will climb about 40%, boosting profit margins to more than 6%

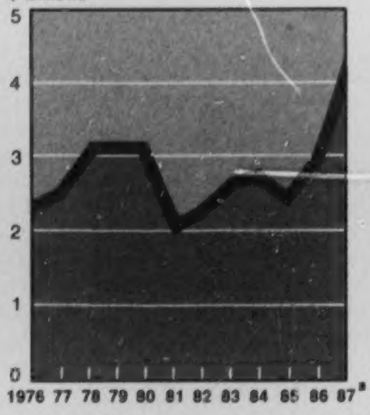
Annual sales

$ Billions



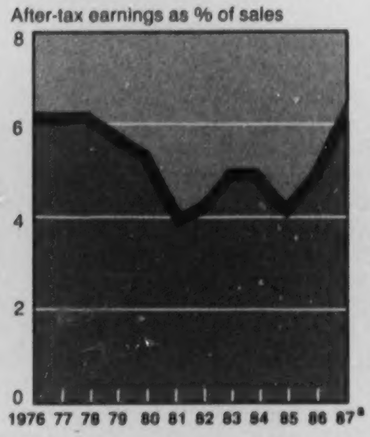
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 12. a C&EN estimates.

Sales and earnings soar for major chemical companies in the third quarter

	THIRD-QUARTER 1987						NINE-MONTHS 1987			
	Sales	Earnings[a]	Change from 1986		Profit margin[b]		Sales	Earnings[a]	Change from 1986	
	($ millions)		Sales	Earnings[a]	1987	1986	($ millions)		Sales	Earnings[a]
Air Products[c]	$ 543.6	$ 39.1	11%	13%	7.2%	7.1%	$ 2,132.2	$ 159.7	10%	31%
American Cyanamid[c]	1,039.0	54.7	13	22	5.3	4.9	3,140.8	203.8	10	36
Aristech	239.7	18.7	28	30	7.8	7.7	676.9	48.3	18	49
Betz Laboratories	100.1	10.8	14	12	10.8	11.0	286.1	30.6	10	8
Cabot Corp.[c]	na	na	na	na	na	4.3	na	na	na	na
Chemed	101.4	6.1	7	46	6.0	4.4	291.4	15.6	9	38
Crompton & Knowles	58.6	2.7	16	40	4.5	3.8	179.2	8.7	12	34
Dow Chemical[c,d]	3,357.0	330.0	22	94	9.8	6.2	6,851.0	891.0	9	56
Ethyl Corp.[c]	440.5	46.3	9	−4	10.5	12.0	1,249.7	140.4	5	6
First Mississippi	79.1	5.8	43	def	7.3	def	240.5	17.8	30	323
Freeport-McMoRan	262.3	53.9	99	258	20.5	11.4	794.0	190.1	73	23
H. B. Fuller	155.1	7.9	14	39	5.1	4.2	443.8	18.5	14	35
Georgia Gulf	176.4	27.9	28	195	15.8	6.9	505.6	56.7	15	105
B. F. Goodrich[c]	564.0	28.8	−2	110	5.1	2.4	1,600.7	63.5	−22	31,650
W. R. Grace[c]	1,100.6	41.0	22	198	3.7	1.5	3,210.6	88.6	20	228
Hercules[c]	653.9	50.3	2	−5	7.7	8.3	2,006.3	158.9	2	−15
International Flavors	187.7	27.1	14	20	14.5	13.7	566.6	85.7	19	25
International Minerals[c]	424.7	19.5	25	def	4.6	def	1,341.2	40.7	13	def
Loctite	94.0	8.8	33	45	9.4	8.6	280.1	27.1	32	42
Lubrizol	236.5	15.4	2	−13	6.5	7.6	778.1	58.1	1	7
Monsanto[c]	1,902.0	100.0	12	23	5.3	4.8	5,793.0	392.0	9	13
Nalco Chemical	216.9	20.3	18	22	9.4	9.0	611.2	58.2	12	22
National Distillers[c]	617.2	27.6	73	922	4.5	0.8	1,824.5	78.5	54	207
Olin[c]	468.5	14.9	14	73	3.2	2.1	1,427.1	61.6	8	−8
Pennwalt	294.1	9.4	8	−33	3.2	5.1	882.5	35.5	7	−10
Petrolite	68.1	3.7	7	62	5.4	3.6	200.6	11.8	−6	−15
Rohm & Haas[c]	540.9	39.3	11	5	7.3	7.6	1,671.3	158.8	5	46
Union Carbide[c]	1,730.0	74.0	11	76	4.3	2.7	5,069.0	209.0	7	80
Vista Chemical	166.6	18.1	19	76	10.8	7.4	608.9	48.5	11	61
Witco[c]	368.8	17.7	9	3	4.8	5.1	1,059.2	50.3	3	3
Total 15 largest companies	$13,750.6	$ 883.1	16%	58%	6.4%	4.7%	$38,376.8	$2696.8	9%	42%
Second 15 companies	$ 2,436.5	$ 236.6	21%	58%	9.7%	7.5%	$ 7,345.4	$ 711.1	16%	29%
GRAND TOTAL	$16,187.1	$1,119.7	17%	58%	6.9%	5.1%	$45,721.9	$3407.9	10%	39%

a Earnings from continuing operations, excluding major nonrecurring and extraordinary items. b Earnings as a percentage of sales. c One of the 15 largest companies. d Averages for 12-month running data do not include Dow Chemical, where figures include a major nonrecurring item, and Aristech and Vista Chemical, for which not all figures are available. def = deficit. na = not available.

decline. Farmers are cultivating fewer acres domestically and more pesticides are being banned from use, hurting pesticide sales. In addition, as pesticide producers develop more potent agents, use per acre will drop, leading to an overall decline in the volume of pesticide production.

New housing permits have been declining since the beginning of the year, according to the Department of Commerce. Though interest rates have recently moderated, offering some hope of new construction activity in the months ahead, the wait-and-see attitude many have adopted because of the recent decline of the stock market may just offset the advantage of lower interest rates.

The Commerce Department also reports that auto output was down in the first half of the year and auto dealer inventories remain high. As a result chemical sales to auto makers may continue to dampen, especially since the much heralded all-plastic-body cars still appear to be years away. However, Chrysler and Ford recently announced plans to step up exports of U.S.-made autos to Europe and Japan by next year to take advantage of the weak U.S. dollar, and chemical makers may benefit from this increase in business.

Despite this litany of drawbacks, which may mean more in the months ahead than for the quarter just passed, production of chemicals and allied products increased 7.4% in the third quarter compared with the year-earlier quarter. The third quarter was not the normal lackluster quarter that past experience would have indicated. Instead, it was the best quarterly output over the past two years.

Prices performed even better. Prices of chemicals and allied prod-

NINE-MONTHS 1987		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1986		Profit margin[b]	
1987	1986	Sales	Earnings	1987	1986
7.5%	7.4%	8%	−10%	7.5%	9.0%
6.5	5.2	9	13	6.1	5.8
7.1	5.7	na	na	na	na
10.7	10.9	5	−19	10.2	13.2
na	4.8	na	na	na	def
5.4	4.2	−4	−17	5.0	5.9
4.6	4.0	−4	3	4.6	4.3
13.0	9.1	10	190	8.4	3.2
11.2	11.1	5	−5	11.3	12.6
7.4	2.3	17	161	5.9	2.7
23.9	33.8	56	36	11.1	12.7
4.2	3.5	16	8	4.1	4.3
11.2	6.3	11	51	10.5	7.7
4.0	0.0	−26	def	4.0	def
2.8	1.0	15	−29	1.3	2.1
7.9	9.5	1	−8	7.0	8.5
15.1	14.5	19	1	14.4	17.0
3.0	def	12	def	1.8	def
9.7	9.0	31	14	9.3	10.6
7.5	7.0	2	−8	7.2	8.0
6.8	6.5	4	65	5.6	3.6
9.5	8.7	9	−10	8.9	10.9
4.3	2.2	1	41	4.6	3.3
4.3	5.1	8	10	3.7	3.6
4.0	4.8	7	61	4.1	2.8
5.9	6.5	−9	−32	5.8	7.7
9.5	6.8	3	2	9.1	9.2
4.1	2.4	5	30	3.3	2.7
8.0					
4.7	4.7	1	−18	4.7	5.8
7.0%	5.4%	5%	51%	5.9%	4.1%
9.7%	8.7%	12%	9%	8.1%	6.3%
7.5%	5.9%	6%	42%	6.1%	4.6%

ucts rose 5.4% from last year's third quarter, according to the Department of Labor. This compares with an increase of 3.6% in the second quarter and a decline of 0.6% in the first quarter. These improvements in prices have gone a long way toward improving earnings leverage in the third quarter despite some small increases in petroleum feedstock prices.

The higher production and prices translate into higher earnings and sales for the chemical industry. For 29 of the 30 major chemical companies surveyed by C&EN (Cabot Corp. had not reported by press time), combined earnings increased 58% from last year's third quarter to a total of $1.12 billion. Composite sales increased to $16.2 billion. The average profit margin (earnings as a percentage of sales) for the 29 firms increased to 6.9% in the third quarter from 5.1% in third-quarter 1986. This is down only marginally from 7.0% in the second quarter, but was still much better than the 6.2% recorded in the first quarter of the year.

The larger companies improved their earnings at the same rate as the smaller companies. For the 14 large chemical companies surveyed, earnings rose an average 58% compared with the same 14 firms' earnings in last year's third quarter to a combined total of $883 million. Sales for these firms increased 16% to $13.8 billion. Their combined profit margin increased to 6.4% from 4.7% in last year's third quarter.

For the 15 smaller firms, earnings also increased an average 58%. Earnings reached a combined total of $237 million, and sales rose 21% to a total of $2.4 billion. Their average profit margin, 9.7%, surpassed that for the 14 larger firms.

For the first nine months, combined earnings for the 29 chemical companies increased 39% from the same period in 1986 to a total of $3.4 billion. Combined sales rose 10% to $45.7 billion. Average profit margin for the group for the first nine months increased to 7.5% from 5.9% in the year-earlier period.

For the 14 larger firms, combined earnings for the first nine months advanced 42% compared with the year-earlier period to a total of $2.7 billion, reflecting large gains particularly in the second quarter of 1987. Sales rose 9% for the group to $38.4 billion; profit margins increased to an average of 7.0% from 5.4% in the first nine months of 1986.

For the 15 smaller firms, earnings during the first nine months grew 29% to a combined $711 million. Sales rose 16% to a total of $7.3 billion, and profit margins for the group were up to a healthy 9.7% from 8.7% in the year-earlier period.

The strong third quarter benefited a number of highly leveraged companies that rely heavily on sales of commodity chemicals to finance their outstanding debt servicing costs. According to James R. Kuse, chairman and president of Georgia Gulf, "Sales volumes are historically high, overall inventories low, and our plants are running at or near capacity levels—all of which indicate the potential for another strong quarter." Vista Chemical's president and chief executive officer John D. Burns was equally elated with third-quarter results. The company's im-

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 32 oil and diversified companies, each with more than $200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Chemical earnings still rising at oil companies

Despite some improvement in the price they receive per barrel of oil, oil companies continue to suffer from low margins in their refining and marketing business sectors. However, their chemical operations again came to the rescue, as they have for the past year, providing solid earnings and profit margins that helped to keep oil companies in the black.

At six of the oil firms surveyed by C&EN that also report net income from chemical operations, moderate raw material prices and higher demand for petrochemicals pushed up earnings in the third quarter. Those six—Amoco, Chevron, Exxon, Mobil, Shell, and Texaco—reported earnings increases ranging from 10 to 407% for the quarter compared with the year-earlier period. Results for the six were also impressive for the first nine months, as earnings increased between 28 and 141% for members of the group.

Texaco, still enmeshed in a fight with Pennzoil over the takeover of Getty Oil, recorded a 33% drop in earnings overall to $108 million. Nevertheless, Texaco managed a 10% increase in its chemical sector earnings to $23 million in the third quarter. It did considerably better in the first nine months; earnings at $50 million were up 28%.

Exxon, the world's largest oil company, recorded a modest 1% increase in earnings for the third quarter to $1.1 billion. Its chemical operations contributed $152 million to this amount, a 33% increase from third-quarter 1986. For the first nine months, Exxon's chemical operations were running well ahead of the same period last year, producing earnings of $563 million, up 60%. Exxon chairman L. G. Rawl attributed the strong showing of the company's chemical operations in particular to demand for olefins, aromatics, and plastics.

Chevron made the most spectacular showing in the third quarter among the six with earnings up 407% to $66 million. "This dramatic improvement," says Chevron chairman George M.

EARNINGS ON CHEMICAL OPERATIONS

	Third quarter		%	Nine months		%
$ Millions	1987	1986	change	1987	1986	change
Amoco	$113	$ 63	79%	$305	$205	49%
Chevron	66	13	407	181	75	141
Exxon	152	114	33	563	352	60
Mobil	92	38	142	210	102	106
Shell	131	53	147	272	201	35
Texaco	23	21	10	50	39	28

Everything.

*Trademark of The Dow Chemical Company

Keller, "is primarily due to ongoing industrywide high sales margins associated with industrial chemicals, coupled with strong demand."

Amoco registered an earnings gain of 79% to $113 million for the quarter. Amoco chairman and chief executive officer Richard M. Morrow noted the strength of worldwide demand for chemicals, as well as favorable results for synthetic fabrics and fibers included in the company's chemical earnings.

At Mobil, chemical earnings increased 142% for the quarter. Company earnings as a whole, however, slipped 4%. Higher margins for polyethylene and polystyrene were largely credited with the chemical operations' strong performance. The company also reported improved plastics business due to both increased volumes and margins for oriented polypropylene films.

proved performance "was a result of the strong markets for all Vista Chemical's products."

Borden Chemical also reported strong commodity sales. According to R. J. Ventres, chairman and chief executive officer of Borden, the parent company, "Customer demand continued strong for polyvinyl chloride resins, leading to higher selling prices and operating income more than double last year's level. Basic chemicals more than tripled in operating income, also reflecting stronger volume and pricing."

Old-line chemical companies performed well, too. At Rohm & Haas, for instance, chairman Vincent L. Gregory Jr. notes that "The pace of business activity in the worldwide chemical industry picked up during the third quarter." In particular, he says, it benefited Rohm & Haas' "polymers, resins and monomers, and plastics segments in the North American, European, and Pacific regions." Unlike petrochemical producers who were in a position to take advantage of increased volume, Rohm & Haas was caught between the prices it paid for feedstock and the prices at which it sells its production. "Offsetting favorable effects of higher volumes were sharp increases in the prices paid for petrochemical feedstocks. As a result, there was shrinkage in our gross profit margin," he says.

More integrated producers had a solid quarter. Du Pont attributed its strong third-quarter showing to demand in such areas as fibers, agricultural, and industrial chemicals and coal, as well as "substantially improved results from upstream petroleum." Du Pont, like much of the rest of the chemical industry, continued to benefit from cost and productivity improvements. According to company chairman Richard E. Heckert, "Third-quarter results demonstrate the ongoing benefit of programs to improve productivity and lower costs."

Continuing weakness in the U.S. dollar also contributed significant-

From Aaaaa to Zzzzz.

The Polyglycol Handbook

Dow polyglycols perform. As everything from perfume stabilizers in bath oils to coating lubricants in sleeping pills. And beyond. Dow's unique alkoxylation capabilities give you the freedom to create new applications with custom ethylene oxide, propylene oxide, and butylene oxide derivatives. For an almost unlimited range of product possibilities. And now, everything you've always wanted to know about polyglycols has been condensed into one invaluable technical resource. The Dow Polyglycol Handbook. And a copy is yours when you call 1-800-258-CHEM. Or circle the reader service number below.

DOW
Polyglycols
The possibilities are endless.

CIRCLE 19 ON READER SERVICE CARD

Earnings improve at many oil firms, and are still rising at most diversified companies

	THIRD-QUARTER 1987						NINE-MONTHS 1987					
	Sales	Earnings[a]	Change from 1986		Profit margin[b]		Sales	Earnings[a]	Change from 1986		Profit margin[b]	
	($ millions)		Sales	Earnings	1987	1986	($ millions)		Sales	Earnings	1987	1986
OIL AND GAS COMPANIES												
American Petrofina	$ 662.5	$ 21.2	37%	274%	3.2%	1.2%	$ 1,812.4	$ 69.7	24%	def	3.8%	def
Amoco	5,164.0	412.0	30	135	8.0	4.4	14,866.0	983.0	7	69%	6.6	4.2%
Ashland	2,047.9	62.5	27	82	3.1	2.1	6,870.9	121.0	−2	−42	1.8	3.0
Atlantic Richfield	4,397.0	315.0	24	209	7.2	2.9	12,244.0	884.0	8	60	7.2	4.8
Chevron	7,700.0	194.0	31	2	2.5	3.2	21,800.0	488.0	2	−34	2.2	3.5
Exxon	21,933.0	1065.0	28	1	4.9	6.1	61,530.0	3285.0	7	−15	5.3	6.8
Kerr-McGee	693.8	21.7	15	def	3.1	def	1,967.0	69.2	1	377	3.5	0.7
Mobil	12,725.0	319.0	30	−4	2.5	3.4	35,643.0	875.0	11	−35	2.5	4.2
Occidental Petroleum	4,222.0	46.0	14	18	1.1	1.0	12,707.0	182.0	14	20	1.4	1.4
Phillips Petroleum	2,800.0	31.0	28	def	1.1	def	7,900.0	2.0	3	−99	0	2.8
Shell Oil	5,654.0	420.0	41	216	7.4	3.3	15,334.0	795.0	19	27	5.2	4.9
Sun Co.	2,470.0	75.0	3	9	3.0	2.9	7,080.0	175.0	−14	−43	2.5	3.7
Texaco	9,000.0	108.0	23	−33	1.2	2.2	26,000.0	355.0	5	−47	1.4	2.7
DIVERSIFIED COMPANIES												
Allied-Signal	2,679.0	92.0	10	−38	3.4	6.1	8,162.0	283.0	11	−37	3.5	6.1
Borden	1,680.0	79.0	32	20	4.7	5.2	4,710.2	185.7	29	20	3.9	4.2
Dexter	193.3	10.2	23	23	5.3	5.3	582.0	32.1	20	26	5.5	5.2
Du Pont	7,585.0	421.0	19	31	5.6	5.0	22,527.0	1199.0	10	1	5.3	5.8
Eastman Kodak	3,913.8	396.1	12	51	10.1	7.5	9,776.0	936.0	15	213	9.6	3.5
Eli Lilly	957.7	150.0	8	11	15.7	15.3	3,034.3	505.5	10	17	16.7	15.8
Emhart	558.3	23.3	18	def	4.2	def	1,789.9	71.5	19	20	4.0	4.0
Engelhard	612.3	14.7	8	21	2.4	2.1	1,751.1	46.3	10	19	2.6	2.5
FMC	730.0	26.8	10	0	3.7	4.0	2,282.8	91.0	3	−11	4.0	4.6
GAF	222.5	31.6	13	29	14.2	12.4	627.8	81.9	10	33	13.0	10.8
Kaiser Tech[c]	523.1	11.9	0	def	2.3	def	1,530.8	−380.7	3	def	def	def
Koppers	434.6	33.1	0	8	7.6	7.0	1,095.4	54.2	3	13	4.9	4.5
Merck	1,306.5	237.6	24	37	18.2	16.4	3,666.9	674.0	23	34	18.4	16.9
3M	2,466.0	249.0	10	16	10.1	9.6	7,054.0	702.0	9	18	10.0	9.2
Morton-Thiokol	557.9	36.4	14	21	6.5	6.1	1,987.3	138.0	2	4	6.9	6.8
PPG Industries	1,260.0	91.3	11	11	7.2	7.2	3,850.0	280.6	12	15	7.3	7.1
Pfizer	1,297.9	185.8	12	5	14.3	15.2	3,644.6	521.7	10	4	14.3	15.1
Tyler	282.6	5.7	15	46	2.0	1.6	816.3	11.9	13	31	1.5	1.3
Vulcan Materials	295.4	38.7	12	5	13.1	13.9	793.1	88.8	10	14	11.2	10.8

a From continuing operations excluding major nonrecurring and extraordinary items. b Earnings as a percentage of sales. c Includes nonrecurring item. def = deficit.

ly to the results for a number of companies included in C&EN's quarterly survey. J. Peter Grace, chairman, president, and chief executive officer of W. R. Grace, says that Grace's specialty chemical company posted gains in physical volume and earnings. Higher income for the unit reflects "the translation effect of the U.S. dollar and improved operating results in Europe, the Pacific region, and in the company's interamerican division."

3M chairman Allen F. Jacobson says that improved earnings at his company also may be attributed to, as he put it, "the more properly valued U.S. dollar," as well as to "an acceleration of our U.S. volume growth, efforts to control costs and assets, and a lower effective tax rate."

Monsanto chairman and chief executive officer Richard J. Mahoney says the company's crop chemicals sales continue to benefit "from the increasing worldwide demand for Roundup herbicide, reflecting the successful implementation of new marketing strategies for that product."

Among the strongest performers for the quarter and indeed for the year was Dow Chemical. According to Dow chairman and chief executive officer Paul F. Oreffice, "Basic chemicals and plastics showed exceptional gains, with continued good balance between supply and demand. Major contributors among basic chemicals included vinyl chloride monomer, chlorine, and caustic. In basic plastics, polyethylene and polystyrene continued to experience strong demand and increasing margins."

The Dow chief also discounted as premature rumors of the decline of the chemical business owing to Wall Street's recent gyrations. "We expect our business to remain strong during the fourth quarter," he says. "This momentum will continue into 1988." □

Sandoz Crop Protection photo

Biologist prepares tobacco hornworms for bioassay of biological insecticide

Pesticides Growth Slows

William J. Storck, C&EN New York

The pesticide business hasn't fallen on hard times, but it isn't the business it used to be. Only a few years ago, many nonpesticide producers were looking with longing at the high profit margins being garnered by pesticide makers. Companies let it be known that they were actively seeking to acquire pesticide businesses, but usually the price was too high. Development of pesticides was a booming business, with each new product being hailed as the ultimate in ridding the world of a particular pest.

Pesticides producers seemed to be almost coining money. Even though the risks were high, R&D soaked up a lot of money, field trials could take years, and the patent protection of an approved pesticide might last for only an average of seven years after introduction, makers could recoup their investment easily. And for some of the major pesticides producers, after-tax profit margins averaged 30 to 40%.

But those days of unending optimism in the industry are over. Companies, like their customers, the farmers, are faced with the realities of the agricultural economy. Despite government programs to cut inventories of farm products, surpluses persist. They are holding down the prices that farmers can receive for their goods and, consequently, are holding increases in farm income in check.

The number of planted acres is down, causing a decline in the amounts of pesticides used. And there are fewer pounds of pesticides used per acre of cropland.

Also there is an increased awareness among farmers—and among pesticides manufacturers—of the safety and environmental consequences of pesticide use. Farmers over the years have been relatively complacent regarding the issue of pesticides and their own health and the health of the environment. This, like so many other factors that farmers face, has been largely a matter of economics. Farmers have felt that their income depended on maximizing output per acre, and pesticides as well as fertilizers and other inputs were all part of that effort. Consequently, farmers tended to take an "overkill" approach to pest management. They often put on more, indeed sometimes much more, pesticide than was necessary to ensure the absolute destruction of pest populations.

In examining the cost of their inputs, however, farmers now have learned that additional pesticides may not be worth the increased cost per acre. And this has been coupled

Pesticides demand slows in U.S.

$ Millions	1970	1985	1990	1995	% annual change 1970–85	% annual change 1985–90
Herbicides	$413	$2675	$3470	$4420	13.3%	5.3%
Insecticides	286	1360	1700	2100	11.0	4.6
Fungicides	120	365	450	555	7.7	4.3
Other Pesticides	83	300	380	475	8.9	4.8
Nematicides	21	85	110	142	9.8	5.3
Rodenticides	13	50	64	81	9.4	5.1
Defoliant's/dessicants	10	45	55	67	10.5	4.1
Fumigants	22	40	47	55	4.1	3.3
Other	17	80	104	130	10.9	5.4
TOTAL	$902	$4700	$6000	$7550	11.6%	5.0%

Source: Freedonia Group

with an increasing environmental and safety awareness among farmers who have seen some of their most frequently used pesticides banned or restricted by environmental pressures.

Last year, *Farm Journal*, a leading agricultural trade magazine, commissioned a study to be conducted by the University of Iowa's Institute of Agricultural Medicine to determine chemical contamination of farmers during the 1986 corn-planting season. Pre-exposure urine samples from 22 farmers in the study showed no contamination. But post-exposure urine samples in some of the farmers—depending on the type of insecticide used—did show low levels of contamination.

The reactions of the farmers are interesting. Most thought that they were being very careful. One is quoted as saying, "I've tried to be a careful handler and did not think I would show up on this test. I use a surgeon's mask and gloves and farm only 275 acres now, but it shows how easy it is to get contaminated." Others tried to pinpoint the cause, saying that, precautions aside, it is very easy to inhale the pesticide or to get it on the skin while handling it.

Donald Morgan, the professor at the Institute of Agricultural Medicine who designed the study, said, "In my experience, it has been unusual circumstances that have led to serious poisonings, rather than well-ordered operations. Broken equipment, spills left unattended, contaminated clothing, skin contact with drips and hoppers during repair—all have led to poisonings. As in so many occupational hazard situations, it is constant vigilance that contributes most to overall safety."

The probability of groundwater contamination also is finding its way into agricultural publications. In August, *Agricultural Resources*, a publication of the U.S. Department of Agriculture's Economic Research Service, published an article entitled "Agriculture's Impact on Water Quality," which does not make any allegations of specific contamination, but rather discusses some of the economic impacts that could occur if certain pesticides were banned from agricultural use. For instance, the article says, "At the national level, widespread changes in agricultural production could affect the market prices of crops. For example, the triazine herbicides, widely used on corn, will be looked for in the [Environmental Protection Agency] survey of pesticides in well water. If these pesticides were banned, corn yields would decrease an estimated average of 8%, raising prices about 31%."

Another USDA publication, *Agricultural Outlook*, this month advises farmers about methods to prevent agricultural pollution of coastal waters from pesticides as well as fertilizer and soil runoff.

This past spring *Farm Journal* tried to make farmers aware of the consequences of groundwater contamination by citing the case of a farmer whose well water was contaminated by pesticides and the resultant economic and emotional impacts on his life.

Other than more careful use, the sheer economics of farm life are cutting into pesticides producers' markets.

Cropland acreage planted this year declined to about 330 million acres, down about 8% from 1986 and off almost 14% from the decade high of 383 million acres in 1982, according to USDA. Further, USDA says, the largest decline—almost 10.6 million acres or about 40% of the total decline—was for corn, the major user of herbicides and insecticides. As a result, total 198 farm pesticide use is projected at 430 million lb of pesticide active ingredients, down 9% from last year.

In looking at other inputs, farmers have learned to be more efficient. Rising costs in the mid- to late 1970s gave farmers an education in managing their inputs that they have not forgotten. The increased cost of just about every product that they had to buy (it has been facetiously said that the American farmer is the only businessman who buys at retail and sells at wholesale) forced farmers to reevaluate just about every sector of their operations. During this period, no-till farming (cropland is not turned under in preparation for planting) or limited-till farming came into practice. The idea was to reduce the number of trips the

Croplands are sprayed with pesticides

Sandoz Crop Protection photo

Tobacco hornworms are used to test potential insecticide candidates

tractor had to make across the field, thus conserving fuel. This concept also resulted in reduced applications of fertilizers and pesticides.

These are cost-cutting practices farmers have not given up, but indeed are extending whenever possible.

According to the U.S. International Trade Commission, shipments of pesticides in 1985 totaled about 1.02 billion lb of active ingredients. This was 14% below the 1986 level and almost 28% below 1985, when the industry peaked at 1.41 billion lb. Although ITC has not yet published figures for 1986, shipments likely recovered and may have reached 1.10 billion lb.

ITC says prices of pesticides generally have increased, more than doubling between 1976 and 1985. However, estimates are that prices declined slightly, probably less than 1%, between 1985 and 1986.

Value of shipments of pesticides has increased 84% between 1976 and 1985, when the value hit $4.44 billion. Most of this growth occurred between 1976 and 1981. Since 1981, the value of shipments has generally trended down except for a large spike in 1984 when it peaked at $4.73 billion. Estimates are that value fell a little more in 1986 to about $4.25 billion.

Against this backdrop then, it is no wonder that makers of agricultural chemicals are saying that the industry is not going to enjoy the growth it once saw.

One of the more optimistic market studies of pesticides has been carried out by Freedonia Group, a

WAM
COPS I
HEM-5
HEM-10

Alcolac offers latex paint manufacturers the following letters of recommendation:

SIPOMER® WAM (Wet Adhesion Monomer) provides excellent scrub resistance and superior wet adhesion.

COPS I (Copolymerizable Surfactant) improves latex mechanical stability.

SIPOMER® HEM-5 and SIPOMER® HEM-10 (Polyethyleneglycol Monomethacrylates) enhances latex stability.

Today, an increasing number of latex paint manufacturers are formulating with WAM, COPS I, HEM-5, and HEM-10 highest quality specialty chemical products from Alcolac.

There's a lot of good chemistry between you and Alcolac.

ALCOLAC

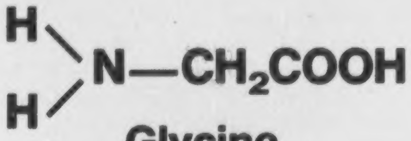
The Specialists in Specialty Chemicals

ALCOLAC INC., 3440 Fairfield Road, Baltimore, Maryland 21226, (301) 355-2600
ALCOLAC LTD., 490 Dufferin Street, Valleyfield, Quebec, Canada J6S 2B4, 514-373-6164

CIRCLE 3 ON READER SERVICE CARD

Need a perfect ending for your next molecule?

Have you ever needed *water solubility* for your great new pharmaceutical, fungicide, herbicide, polymer, thickener, dispersant, or other organic reaction product? Well, here's a way:



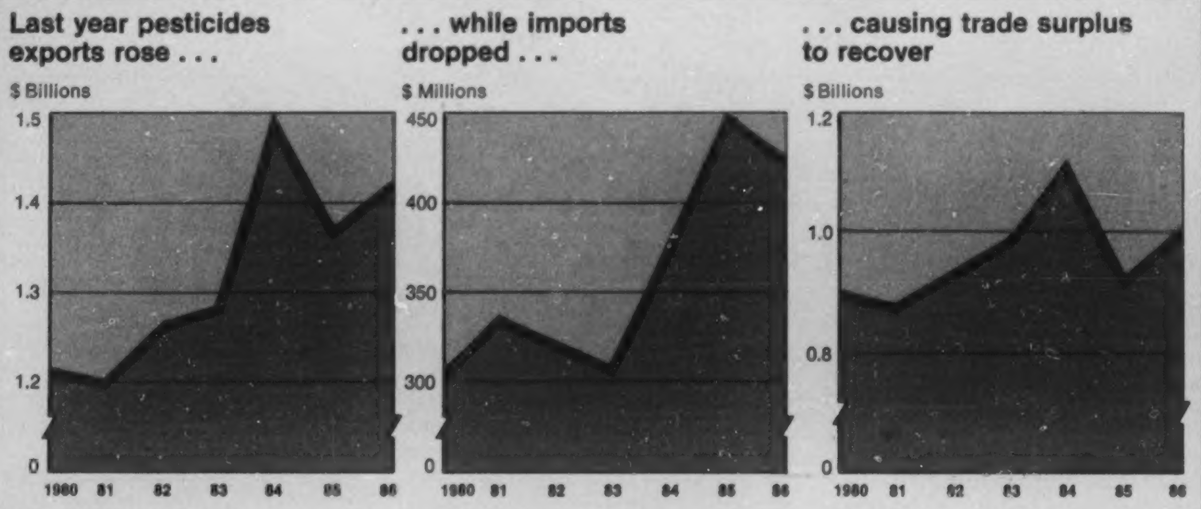
Glycine

Glycine has a convenient, reactive amino group so you can add this water-soluble terminal group to your favorite organic compound. We have 28 pages of ideas for you to choose from. That's something to react to.

GRACE

Organic Chemicals Division, W. R. Grace & Co.
55 Hayden Avenue, Lexington, MA 02173 (617) 861-6600 X2803

CIRCLE 28 ON READER SERVICE CARD



Last year pesticides exports rose . . .

. . . while imports dropped . . .

. . . causing trade surplus to recover

Source: Department of Agriculture

market research firm based in Cleveland Heights, Ohio. This study shows pesticide demand in dollar volume growing at 5.0% per year between 1985 and 1990. However, this is a slowing from an 11.6% annual average growth rate between 1970 and 1985. For agricultural use of pesticides, the projected growth rate over the 1985-90 period is again 5.0% per year, down from 11.2% annually between 1970 and 1985.

Growth in pesticide use, the study says, will be based on favorable economic factors, moderate agricultural advances, and continued technological innovation. But, it adds, because of more efficient formulations, volume demand for pesticides will drop slightly. The study also says that biological control measures such as the use of resistant crop varieties and natural predators will not replace pesticides in the next decade.

Herbicides will exhibit the most rapid growth over the next five years (about 5.3% per year to $3.47 billion), aided by technological advances, according to the study. Corn and soybean producers will remain the two largest markets. High-activity products based on new chemistries have been developed that permit significantly lower application rates, employ different modes of action, and improve environmental safety. The study particularly cites American Cyanamid's imidazolinones—Arsenal, Scepter, and Assert—and Du Pont's sulfonylureas—Glean, Escort, and Harmony—as examples.

The study says that insecticides and fungicides will have more limited markets and fewer technological breakthroughs than will herbicides. Competitive pressures will force insecticide producers to fund research activity to develop new generations of synthetic pyrethroids and to seek acquisitions in order to broaden markets. Development of a new breed of fungicides known as sterile inhibitors is expected to have a significant impact on fungicide markets. Sterile inhibitors stop fungal attack and provide residual protection with fewer applications.

A more pessimistic view is offered in a study by Frost & Sullivan, the New York City-based market research firm. It says that the size of the agricultural chemicals market is unlikely to change appreciably during this decade. The Frost & Sullivan study indicates that since virtually all planters who might use agricultural chemicals are already using them, growth would require an increase in planted acreage. And, the study points out, such acreage might decline over the next few years because of foreign demand reductions or supply increases, breakthroughs in agricultural productivity, or further declines in U.S. consumption of meat, which is a relatively expensive food in terms of planted acreage support required.

And there will be factors other than gross demand shifts that will affect the pesticides industry in coming years, according to the study. For instance, the ending of patent protection for many major products will mean a rapid shift from a proprietary market structure to one subject to commodity competition. This will mean increased direct competition, lower prices, and lower profitability for all pesticide producers and is likely to result in increased consolidation of the industry. It may also mean an increase in the importance of formulators.

The industry is already consolidating. Over the past few years, Farley/Northwest Industries has sold its Velsicol operations to Sandoz; Union Carbide's agricultural chemicals operations went to Rhône-Poulenc; Du Pont has bought Shell Chemical's pesticides operations; and BASF has purchased Rohm & Haas' Blazer herbicides business (Rohm & Haas has retained its other agricultural chemicals operations). In addition, Stauffer's agricultural chemicals business is now owned by ICI, and Diamond Shamrock's pesticides business has been taken over by Fermenta.

One other change was the acquisition of Uniroyal's agrochemicals business by Avery Inc. However, this does not reflect a consolidation—the move was mainly because of a failed takeover attempt of Uniroyal and its subsequent selling off of assets.

Common to all these deals—except Du Pont's acquisition of the Shell business—is a foreign buyer.

This may be a coming trend, according to industry observers. Payout in the agricultural chemicals business is becoming so long-term U.S. companies may not want to take the risk. Environmental pressures have forced companies to extend their testing, and the rate of success in developing new products is dwindling. An estimated 25,000 to 30,000 compounds must be synthesized to find one commercial product. In addition, there is a reluctance in the marketplace to change from a familiar and effective product to a new product until the new pesticide has proven itself.

These factors, according to industry sources, are among the reasons that foreign companies are buying the U.S. chemical operations. Foreign companies want to get into the pesticides market and, in most cases, they are more willing to enter into long-term investments. They are willing to wait for their returns, whereas U.S. companies demand shorter-term profits. For this reason, pharmaceutical companies or chemical companies with large pharmaceutical operations, such as Eli Lilly, Ciba-Geigy, American Cyanamid, and Sandoz, are more comfortable with pesticides. These companies are thoroughly familiar with many of the strictures placed on pesticides—the testing and justification that may cost more than $20 million per compound, patent protection problems, and the wait for profits—because the strictures are also common in the drug industry.

According to a study by Technomics Publishing Co., Lancaster, Pa., of the top 10 pesticide companies in 1970, only six remained in the top 10 in 1986. Of the top 10 in 1970, only two were foreign-owned. By 1986, five were foreign-owned. Since that time, there has been further consolidation of the top 10 firms, with Du Pont's acquisition of Shell's business and ICI's purchase of the Stauffer pesticides operations.

The slowing of the pesticides industry is showing up in other ways as well. For instance, the number of new products introduced each year has declined significantly over the past 15 or so years. In the mid-1960s, the number of new compounds being registered peaked at about 40 per year. This has slowed to less than 10 per year.

Industry sources say that they are not particularly concerned by this decline because the pesticide industry has always gone through peaks and valleys in new product registrations. They point to the fact that R&D spending is probably at an all-time high in the U.S. pesticides industry, with the basic chemicals industry spending more than $850 million per year on R&D.

Even though the companies may be spending more on R&D, the question is just where is that money going? Is it going to new product development or is it going to defend products? There is no ques-

Sandoz Crop Protection photo

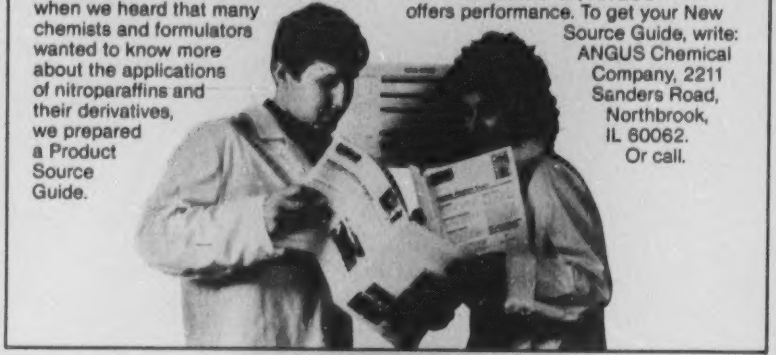
Bacterium used in biological insecticides is examined for potency

ANGUS PERFORMS™

We heard you when you asked for more data on the uses of nitroparaffins and their derivatives.

If you seek new products or improved products, ANGUS' leadership and experience in NP's can be invaluable. So when we heard that many chemists and formulators wanted to know more about the applications of nitroparaffins and their derivatives, we prepared a Product Source Guide.

ANGUS also offers sampling, technical assistance and an unmatched data base. But best of all, ANGUS offers performance. To get your New Source Guide, write:
ANGUS Chemical
Company, 2211
Sanders Road,
Northbrook,
IL 60062.
Or call.



ANGUS®
CHEMICAL COMPANY

AC-9137

Call 800/323-6209. In Illinois, call collect at 312/498-6700. © 1987, ANGUS Chemical Company

CIRCLE 6 ON READER SERVICE CARD

tion that the cost of developing a new product is rising. In the past five years the "hurdle rate" to get through preregistration testing has increased because of government demands for greater toxicity testing, metabolism tests, and studies of residues, soil, and groundwater effects. As a result of delays in registration caused by the increased testing demands, the effect on profits can be enormous. For a "blockbuster" product—one rapidly accepted with high sales—a one-year delay could mean a loss of profits in millions of dollars.

Companies also must spend more to reregister products when a patent expires because the government is demanding more data than ever before. According to Will D. Carpenter, vice president, technology division, Monsanto Agricultural Co., the cost of generating these studies may be greater than the annual sales volume of the product. Because of this increased cost, he says, there is attrition of products in the marketplace. This attrition could accelerate, he adds, as testing demands increase.

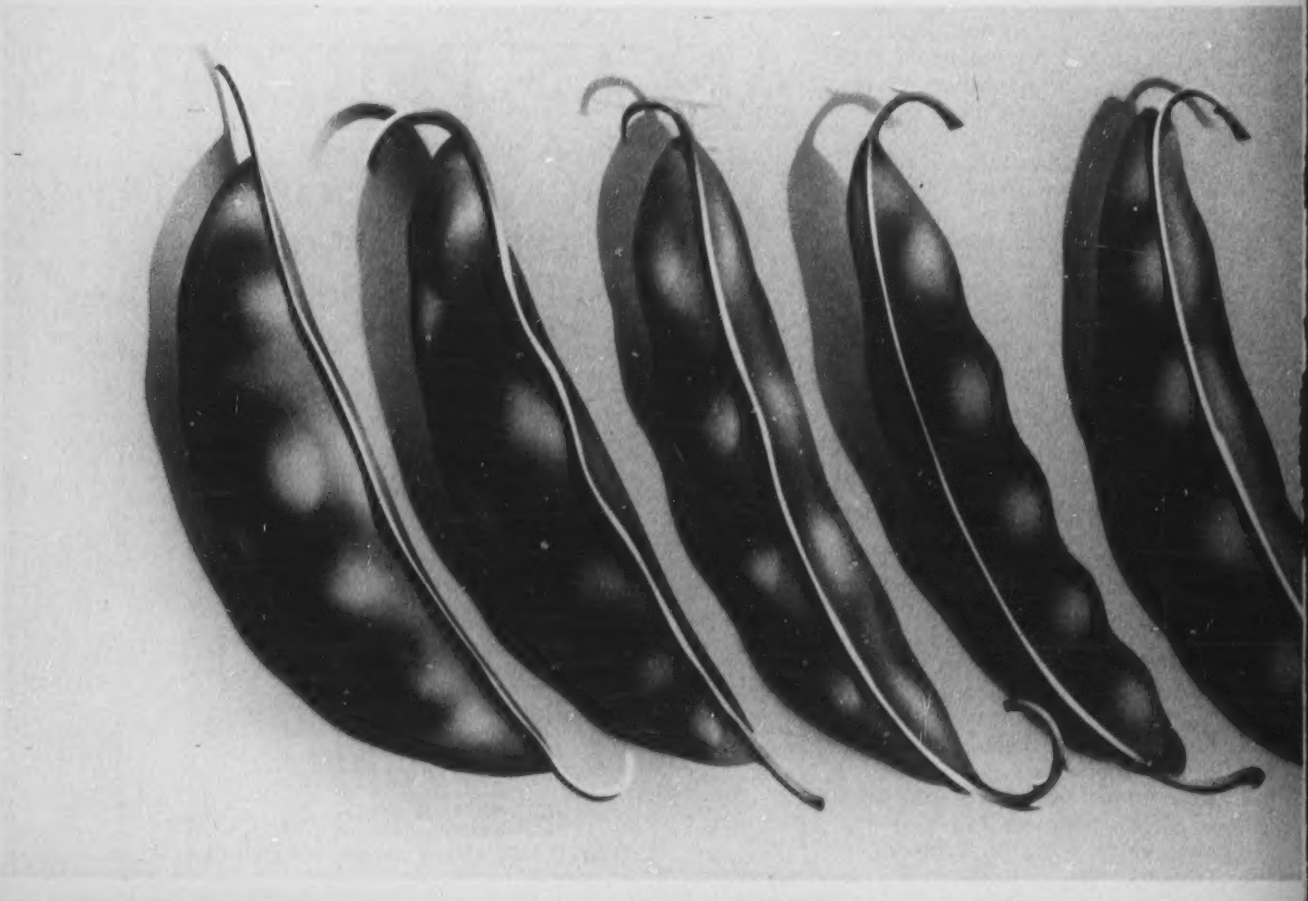
Thus, manufacturers are not considering growth; they are now worried about shrinkage. This means fewer products, fewer manufacturers, increased competition among products, and lower profits.

Dale Miller, president and chief executive officer of Sandoz Crop Protection Corp., says that some of the shrinkage stems from better educated farmers—they understand better what they need and what they don't need. Also, many of the markets expected in the 1970s have not developed. The major market anticipated was the developing countries, where there are large demands for food and fiber. Producers believed that South America, particularly Argentina and Brazil, would become a fertile market. This market did not materialize, in spite of the fact that

Europe takes largest share of U.S. pesticide exports

% of exports[a]	1986	1985	1984	1983	1982
Africa	3.8%	2.9%	3.8%	3.1%	3.3%
Canada	9.3	12.7	13.2	13.9	12.9
Central America	8.0	9.0	8.8	8.7	9.5
South America	15.9	12.0	13.0	13.3	12.5
Asia	22.9	22.9	22.5	22.8	22.6
Western Europe	35.3	36.0	33.4	32.4	35.1
Eastern Europe	0.9	0.6	0.2	0.3	0.4
Oceania	3.8	4.0	5.1	5.5	3.6

a Totals may not add up to 100 because of rounding. Source: Department of Agriculture



many South American countries are better able to feed and clothe their populations than 10 years ago. According to Miller, these countries not only learned to manage their inputs better, but they also became more efficient in bringing their crops to market.

Brazil has been importing more pesticides from the U.S., but only in the past two years. In 1986, according to USDA estimates, Brazil accounted for 5.8% of total U.S. pesticide exports, up from 3.5% in 1985, but little more than the 5.5% taken in 1983.

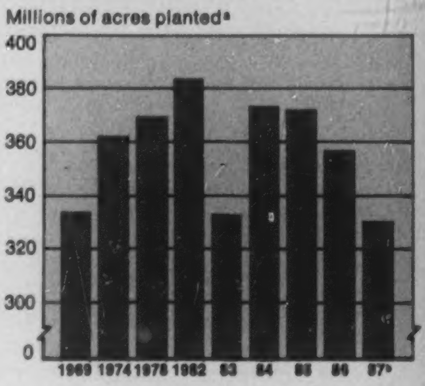
In spite of the strong dollar in the early 1980s, pesticide exports have been the bright spot of the pesticide industry. According to USDA, the value of pesticide exports increased to $1.4 billion in 1986 from $1.2 billion in 1980, peaking at $1.5 billion in 1985. Industry predictions are that exports will increase again in 1987, perhaps surpassing the 1985 level.

Herbicides represent the biggest share of pesticide exports, constituting about 44% or $625 million worth of product sent overseas. This is followed by insecticides at 36% or $513 million and fungicides at 16% or $222 million. Between 1980 and 1986, herbicides were the fastest growing segment at about 29%, followed by fungicides at 13%, and pesticides at 13%. The fastest growing subcategories were miscellaneous formulated insecticides at 135% and technical herbicide materials at 51%.

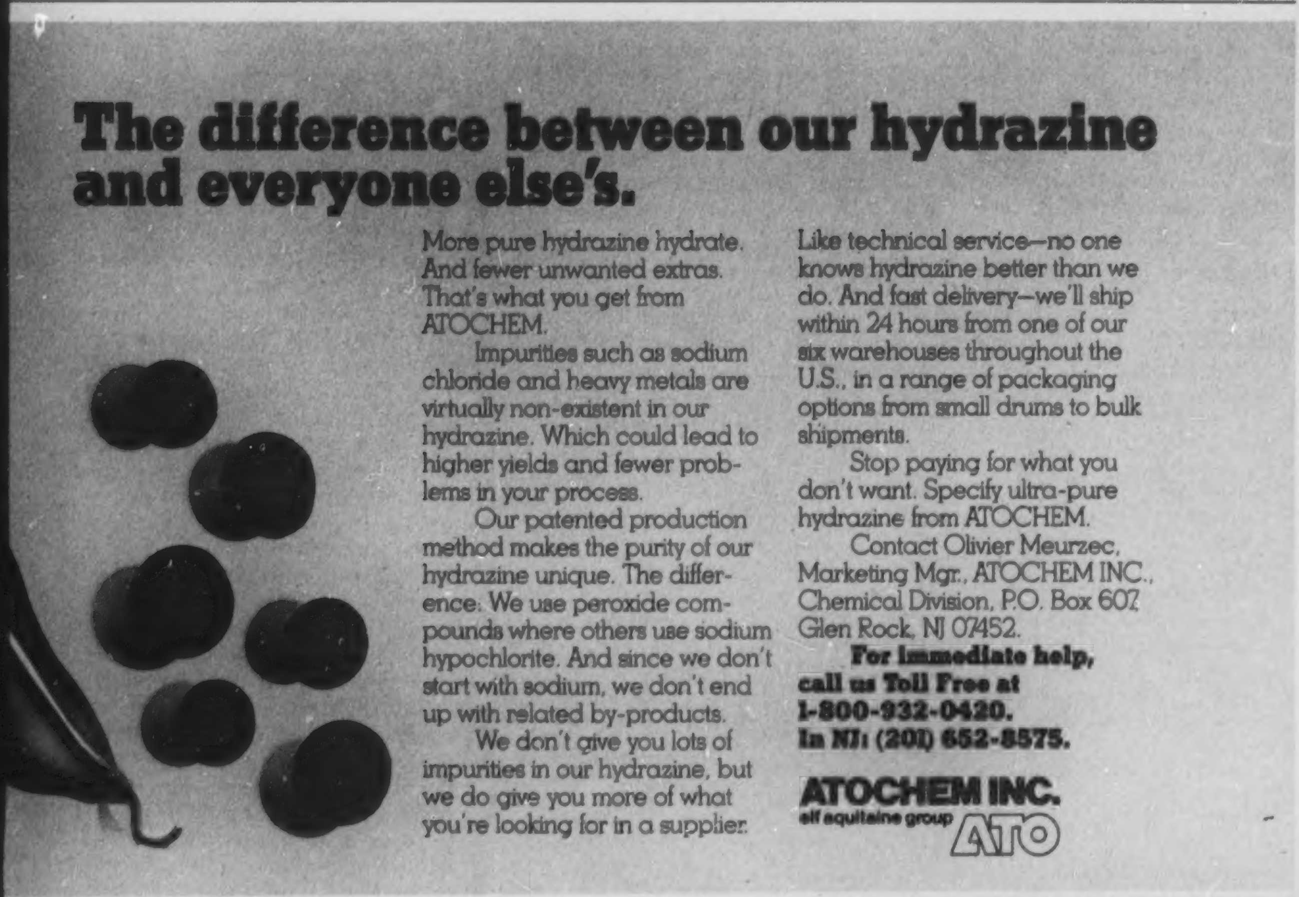
The greatest decline came in chlorinated hydrocarbon insecticides, according to USDA, exports of which fell from about $18 million in 1980 to about $1 million in 1986. The last DDT production plant closed in 1983, which, coupled with increased foreign production of related products, contributed to the decline in exports of these insecticides.

Pesticide imports also grew between 1980 and 1986, peaking again in 1986. In the 1980–86 period, imports rose 37% to $423 million with the 1985 high at $449 million. Most of this import trade is in technical material, the active ingredient for the pesticide. Formulated products make up 20% of total imports since it is cheaper to ship just the technical material. However, the value of

Land used for crops will decline again this year



a For 48 contiguous states. b Preliminary.
Source: Department of Agriculture


The difference between our hydrazine and everyone else's.

More pure hydrazine hydrate. And fewer unwanted extras. That's what you get from ATOCHEM.

Impurities such as sodium chloride and heavy metals are virtually non-existent in our hydrazine. Which could lead to higher yields and fewer problems in your process.

Our patented production method makes the purity of our hydrazine unique. The difference: We use peroxide compounds where others use sodium hypochlorite. And since we don't start with sodium, we don't end up with related by-products.

We don't give you lots of impurities in our hydrazine, but we do give you more of what you're looking for in a supplier.

Like technical service—no one knows hydrazine better than we do. And fast delivery—we'll ship within 24 hours from one of our six warehouses throughout the U.S., in a range of packaging options from small drums to bulk shipments.

Stop paying for what you don't want. Specify ultra-pure hydrazine from ATOCHEM.

Contact Olivier Meurzec, Marketing Mgr., ATOCHEM INC., Chemical Division, P.O. Box 607, Glen Rock, NJ 07452.

For immediate help, call us Toll Free at 1-800-932-0420. In NJ: (201) 652-8575.

ATOCHEM INC.
elf aquitaine group ATO

CIRCLE 9 ON READER SERVICE CARD

formulated product imports has increased 90% over the past six years whereas imports of technical material have increased 27%.

As a result, the trade surplus in pesticides also has grown, but it peaked in 1984. From 1980 to 1986, the surplus increased 11% to $1 billion. It peaked in 1984, at $1.12 billion.

Ironically, Brazil, forecast in the 1970s to be a large market for U.S. pesticide exports, today exports a large volume of pesticides to the U.S. Although it imported about $83 million in pesticides from the U.S. in 1986, it exported about $55 million to the U.S. This made it the second largest supplier of pesticides to the U.S., trailing only West Germany. USDA, however, hints that some of this trade may be the result of transshipping products to the U.S. through Brazil, which is given favorable tariff treatment.

Exports to the Third World still figure into any equation for the future of the pesticide industry, but the equation may take a new twist. This twist involves a general trend to improved products and new formulations that dramatically reduce the amount of active ingredient needed per acre of cropland, and how industry will cope with the problem it creates.

The problem is educating the farmers. Companies have horror stories of poorly educated farmers in developing countries vastly overapplying pesticides to their crops. So there is the fear that a combination of misreading labels plus a misguided "if one ounce is good, one pound will be great" attitude will damage perhaps both the crop and the environment.

According to Monsanto's Carpenter, pesticide makers are well aware of this problem and are studying ways to avoid it. One of the ways, he says, will be to ship the product premixed. This solution has its own set of problems—economic, not environmental. Companies will largely be shipping water, and somebody will have to pay for that water. Will it be the farmer in the developing countries or will it be the chemical company? This is the unanswered question.

The next few years may see further changes in the U.S. agricultural chemicals industry. The Freedonia study says that besides the acquisitions that increase market penetration and provide research dollars, business strategies include seeking licensing agreements to offset patent expiration and high research costs. Many companies are turning to more efficient, value-added operations such as premixing of different herbicides or of herbicides with insecticides or fungicides to offset decreased sales and save time and fuel. And the industry will continue to focus on new product development with a view to finding its own niche in the marketplace.

Sandoz Crop Protection photo

Mode-of-action studies test activity of potential herbicide candidates

Prices of most pesticides fell over past two years

$ per lb active ingredient	1987	1986	1985	% annual change 1987	% annual change 1986
HERBICIDES					
Alachlor	$4.84	$5.10	$5.15	−5.1%	−1.0%
Atrazine	2.20	2.14	2.04	2.8	4.9
Butylate	3.04	3.10	3.13	−1.9	−1.0
Cyanazine	4.62	4.55	4.55	1.5	0.0
Metolachlor	6.03	6.05	6.09	−0.3	−0.7
Trifluralin	6.30	6.25	6.43	0.8	−2.8
2, 4-D	2.44	2.26	2.38	8.0	−5.0
Composite[a]	4.05	4.05	4.06	0.0	−0.2
INSECTICIDES					
Carbaryl	3.90	3.91	3.84	−0.3	1.8
Carbofuran	9.57	10.27	10.29	−6.8	−0.2
Chlorpyrifos	8.25	8.30	8.23	−0.6	0.9
Fonofos	8.70	8.82	8.85	−1.4	−0.3
Methyl parathion	2.82	2.74	2.75	2.9	−0.4
Phorate	6.59	6.54	6.57	0.8	−0.5
Synthetic pyrethroids	48.80	51.20	54.40	−4.7	−5.9
Terbufos	9.79	9.79	9.80	0.0	−0.1
Composite[a]	10.25	10.27	10.49	−0.2	−2.1

[a] Includes major materials not listed. **Source:** Department of Agriculture

Changing farm technology also may have its effect. According to the Frost & Sullivan study, conservation tillage will shift use toward surface-applied pre-emergent and postemergent products and away from products that are incorporated into the soil. This shift is already under way. And Frost & Sullivan says the growing use of personal computers will enable farmers to tailor pesticide requirements to the economics of the individual operation. Again, this may be just a more sophisticated method of doing what the farmer already is doing, reviewing his inputs and streamlining wherever possible.

Most industry sources agree that in the next 10 years biotechnology-derived pesticides won't have much impact because it will take about that long for them to receive their registration. And, these sources estimate, in 20 years, only 5 to 15% of the pesticide outlay by farmers will be for biotechnology-derived products. □

CIRCLE 49 ON READER SERVICE CARD →

A1250-1
11/25/87

NOVEMBER 23, 1987

CHEMICAL & ENGINEERING

NEWS

Jach Conley
93 2nd St.
S.F. 94114
Mark Richard
A Better Place
TOM CASTRO
HEAL AIDS WITH LOVE

0511179C098 9 K AR6547SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

A C&EN SPECIAL ISSUE

AIDS The science of a human tragedy

Volume 65, Number 47
CENEAR 65 (47) 1-88
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

NOVEMBER 23, 1987

News of the Week

- **EPA extension of deadlines for meeting clean air standards draws strong criticisms.** Page 4
- **Hoechst Celanese plant in Pampa, Tex., is site of two explosions and ensuing fire that killed three people and caused extensive property damage.** Page 4
- **Genentech receives FDA approval to market blood clot-dissolving drug, Activase.** Page 5
- **In Bhopal case, Union Carbide and the Indian government fail to reach a settlement by court-issued deadline.** Page 5
- **Clayton Callis, vice president of environmental consulting firm Chelan Associates, has been elected ACS's 1988 president-elect.** Page 6

Cover: Portion of an enormous quilt that commemorates more than 1900 persons who have died of AIDS. The quilt was unfurled in a ceremony on the Mall in Washington, D.C., in October. Photo by C&EN's Ron Dagani

Letters 2
Concentrates
Business 9
Government 10
Science/Technology 11
The Departments
Books 69
Awards 71
Newscripts 88

The tragic story of AIDS is a maelstrom of scientific, public health, social, moral, and policy issues. Page 12

The Molecular Biology

Scientists worldwide mount an intensive research effort in their quest to understand the structure and genetics of HIV, the virus that causes AIDS, and identify weaknesses that might lead to therapies. Page 14

The Search for Vaccines

Variety of AIDS vaccine strategies are being investigated and a number of potential vaccines have been developed but success, as yet, seems on the far horizon. Page 27

The Problem of Diagnostic Tests

Researchers' goals for second-generation HIV diagnostic tests include greater sensitivity and specificity, while improving on speed, simplicity, cost, and safety. Page 35

The Quest for Therapy

Dozens of potential drugs are being tested as either antiviral or immune-restoring agents, but so far the only approved therapy is the high-priced drug zidovudine. Page 41

The Public Health Challenge

Public health issues associated with AIDS engage the country in legal and ethical exchanges involving testing and education, pitting the public good against individual rights. Page 50

The Government's R&D Policy

Federal government's initial stance on AIDS begins to change as research and development funds become available, and policy "system" is formulated. Page 59

The Business Response

The business community is actively involved in the development of vaccines, drugs, and diagnostic tests, despite scientific, medical, and business uncertainties. Page 66

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Wilbert C. Lepkowski, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Joyce A. Richards (Head), Anne Riesberg (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve

© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 87)

LETTERS

Improving public image

SIR: I have just read the official statements by the ACS presidential candidates and have dutifully voted. Both candidates sound like fine persons and our society is lucky that such people have a desire to serve.

I am writing this letter for the many thousands who wish to beg and plead that the winning candidate not increase the dues, which seem to creep incessantly upward. Some of us are definitely not as well off as others and the yearly dues bill does hurt.

I agree that much needs to be done and our public image needs much help. It will all take money. Please be creative when it comes to raising funds. Put the strong arm on industry, which is fundamentally responsible for the image problem we have. Convince industry that they help themselves by helping us. Industry should donate big money to ACS. The time for this idea has come.

My final thought has to do with how to spend the money to improve our public image. Spend the money on truthful things and not on slick advertising that the public has become too sophisticated to swallow. As scientists we must all latch hold of the new truth—the biosphere of our Earth is finite and we must stop harming it. We must push for new laws and agreements that allow competitive capitalism to continue without a dead environment as the side effect.

Dennis Baker
Makawao, Hawaii

Nonscientific programs

SIR: At the recent ACS Council meeting in New Orleans, I raised the question of the suitability of permitting four firms to peddle schlock to registrants and attendees at the exposition. I now note that the chairman of the Membership Affairs Committee lists three criteria for determining whether nonscientific programs shall be considered for offering to members (C&EN, Aug. 31, page 47). These are, briefly, availability to the majority of members from other sources; expense to the society; and income to the society—and they require a "No," "No," and "Yes" answer to be approved.

On this basis, I realize that relatively few ACS members have access to a world-class symphony; can we then sponsor a speakers bureau tour for Solti and the Chicago Symphony? Perhaps we can look forward to Bruce Springsteen appearing before the East Podunk Section. I may find it not only inconvenient but a bit embarrassing to have to travel quite a distance to purchase an X-rated video. Could C&EN add a lonely hearts section to its very productive want-ad department?

In discussing the matter with other councilors after the meeting, I find that there are some who feel strongly that the "Travel Department" does not belong in our programs. Some others, possibly fewer in number, feel that peddling a charge card does not come under the mandate of our charter. Still others may object to one or all phases of the insurance program. Although there obviously will not be any unanimous opinion on where we should draw a line, I believe that at least the majority of our members feel that there should be a line.

James J. Doheny
Brookfield, Ill.

Doctorate in chemical research

SIR: A novel concept, which proposes the awarding of an alternate doctorate to qualified chemical researchers by ACS, is presented in the letter of David R. Schryer (C&EN, March 16, page 33). This idea is both timely and meritorious. It is fraught with promising possibilities and deserves serious consideration. Responding to Schryer's letter, Kurt J. Rorig (C&EN, May 25, page 2) suggests the granting of a certificate entitled, "Diplomate in Chemical Research (Dipl. C.R.)." This terminology is intended to avoid interference with the domain and authority of a university to grant the degree of Ph.D. and also the honorary Ph.D. Rorig's certificate of Dipl. C.R. seems reasonable, but it appears to dilute to some degree the honor and prestige of the Ph.D.

Consequently, the problem of finding a more suitable designation for chemical research achievement (particularly in the industrial field) would boil down to a consideration of the difference between granting a degree and a title. There is a specific difference. Then too, since the Ph.D. is considered to be a research degree, then the alternative would be a research title. Accordingly, I wish to suggest the use of the wording, "confer the title of Doctorate in Chemical Research (D.C.R.)" in an appropriate certificate granted by ACS. I am inclined to believe that it would be in the domain and privilege of ACS to establish and grant a certificate of this kind to its qualified colleagues. This privilege would be a plus to the prestige of ACS, and also

The Government's R & D Policy

After a slow and contentious start, the federal R&D effort aimed at combating AIDS is taking shape, as funds flow and organization evolves

Wil Lepkowski, C&EN Washington

Of all the science policy issues the federal government and the scientific community have had to deal with over the years, none has touched raw nerves so much as the scourge of AIDS and the drive to halt it. Acquired immune deficiency syndrome is a domestic and international disaster.

Hope persists that human immunodeficiency virus (HIV) will continue to keep its distance from the general heterosexual community, only marginally affected up to now. But the heterosexual middle class in the U.S. could be quickly galvanized if the virus does begin to sweep through that population. It is a prospect scientists, policymakers, and politicians dread.

The struggle against AIDS, therefore, is a huge challenge for science, and an enormous policy task.

After early Administration confusion, infighting, and failure to recognize the urgency of the epidemic, the funding is now beginning to pour in. When Congress gets through with appropriations at least $1 billion will be approved for the current fiscal year in funds for research, treatment, diagnosis, and education by the U.S. government. The sums will likely rise year by year and approach a total of $2 billion if scientists involved in advisory roles get their way.

The basic fact about AIDS transmission, however, is the one Mr. & Mrs. America find most difficult to digest: that it was spread throughout the country mainly by anal intercourse between promiscuous homosexuals. Thus the major barrier to a national AIDS "dialogue" is the public's traditional antipathy toward that group and skittishness concerning explicit sexual descriptions in educational materials. Moralistic attitudes were so strong that only this year did President Reagan deliver an address on the specific topic of AIDS.

Conservative politicians and the Administration want AIDS policy to reflect traditional Christian moral values and not be seen as condoning homosexual practice, premarital sex, or drug abuse. Unfortunately, those "values" sometimes take the politically inflammatory form of outlawing private behavior and quarantining AIDS patients.

Homosexuals, meanwhile, want attention directed more at the need to curb and eliminate the virus. Scientists want to get on with the basic research, the search for a drug, and with straight talk on changing sexual behavior and the practices of drug addicts to closet the virus and slow down its spread.

Because of President Reagan's difficulty in insisting that his Administration speak with a single voice on the subject, most observers feel that AIDS will become even more political than it already is, drawing scientists more deeply into the fray. "It's bound to be a major issue in the election; I can't imagine it will not be," says Institute of Medicine president Samuel Thier. The institute has been at the forefront of AIDS policy issues, with a landmark report issued last year in combination with the National Academy of Sciences and several meetings on the subject. He expects political controversy to intensify.

One Republican candidate, Pat Robertson, for example, told a Rockford, Ill., audience late last month that scientists were "misleading the public" in saying AIDS is spread only by sexual contact. "I don't think scientists are telling the truth about AIDS," he said. In arguing in favor of such measures as possibly quarantining AIDS victims and making AIDS testing mandatory for high-risk groups, Robertson said, "I do not know of any virus that has a civil right." Robertson was not in fact reporting correctly the judgment of scientists. Thier's Institute of Medicine Committee for a National Strategy on AIDS has said AIDS is spread not exclusively,

Fauci: perceptual gaps should close

only mainly, by sexual contact. In its report it listed all the other means of transmission.

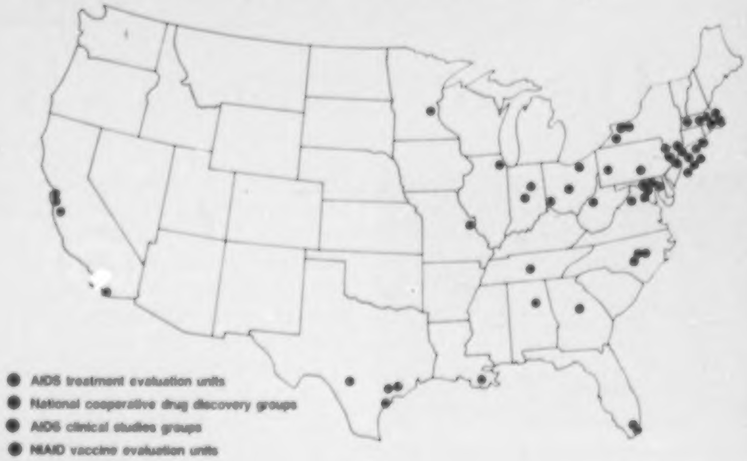
That is why the biomedical community feels that it must be seen as a sea of calm purpose as the AIDS policy debate matures. "The perception is just as important as the reality," comments David Baltimore, director of the Whitehead Institute for Biomedical Research in Cambridge, Mass. Baltimore meant that the public must have confidence that the scientific community is working in the interest of the public in a unified attempt to develop drugs and vaccines, and to inform the public in plain language on the facts of the disease and on new developments as they occur.

That community got off to a credible start with the release last September of the Institute of Medicine/NAS report, "Confronting AIDS," seen as the definitive policy document on the subject. It was hoped that the study would alleviate the poor press that scientists received in the early 1980s, when the AIDS outbreak was taking the form of a national emergency.

Then, AIDS news was monopolized by conflicts between French scientist Luc Montagnier and his American counterpart, Robert C. Gallo of the National Cancer Institute, over discovery of the HIV virus, as well as fierce infighting between NCI and the Centers for Disease Control over research leadership. Since then, the National Institute of Allergy & Infectious Diseases (NIAID), headed by Anthony S. Fauci, has become the lead research agency in the AIDS program and intragovernmental tension has decreased significantly.

With the major bureaucratic battles pretty much over, an AIDS policy "system" is slowly taking shape. It has four major components: research, the drug and vaccine development related to it, education, and testing. All are related. Political ideology has an impact on all of them, especially infusing education and testing. But whereas education and testing issues remain unresolved and await legislation and policy, the technical aspects are pretty clear-cut: find treatments and a cure for AIDS. The major issues include:

NIH funds network of AIDS centers across U.S.


● AIDS treatment evaluation units
● National cooperative drug discovery groups
● AIDS clinical studies groups
● NIAID vaccine evaluation units

AIDS treatment evaluation units

Memorial Hospital for Cancer & Allied Diseases, New York City
Johns Hopkins Hospital, Baltimore
U of Washington, Seattle
U of Miami, Miami
Massachusetts General Hospital, Boston
Tulane U Medical Center, New Orleans
Institute for Immunological Disorders, Houston
San Francisco General Hospital, San Francisco
Albert Einstein College of Medicine, New York City
New York U Medical Center, New York City
U of Minnesota Health Science Center, Minneapolis
Duke U Medical Center, Durham, N.C.
U of Rochester, Rochester
UCLA School of Medicine, Los Angeles
U of Pittsburgh, Pittsburgh
USC Medical Center, Los Angeles
Stanford U School of Medicine, Stanford
Mount Sinai Medical School, New York City
U of California, San Diego

National cooperative drug discovery groups

Memorial Sloan-Kettering Cancer Center, New York City
Duke U Medical Center, Durham, N.C.
Purdue U, West Lafayette, Ind.
U.S. Army Medical Research & Development Command, Fort Detrick, Md.
U of Texas Medical Branch, Galveston, Tex.
Stanford U School of Medicine, Stanford
Biogen, Cambridge, Mass.
Dana Farber Cancer Institute, Boston
U of Miami School of Medicine, Miami
George Washington U School of Medicine, Washington, D.C.
Emory U School of Medicine, Atlanta
State U of New York School of Medicine, Buffalo
State U of New York School of Medicine, Stony Brook
U of Alabama School of Medicine, Birmingham
City of Hope National Medical Center, Duarte, Calif.
Worcester Foundation for Experimental Biology, Worcester, Mass.

AIDS clinical studies groups

U of Texas Health Science Center, San Antonio
U of Massachusetts Medical School, Worcester
New Jersey Medical School, U of Medicine & Dentistry of New Jersey, Newark
Milton S. Hershey Medical Center, Hershey, Pa.
Ohio State U Medical Center, Columbus, Ohio
U of Cincinnati College of Medicine, Cincinnati
Robert Wood Johnson Medical School, U of Medicine & Dentistry of New Jersey, Piscataway
St. Luke's/Roosevelt Institute for Health Sciences, New York City
Indiana U School of Medicine, Indianapolis
Case Western Reserve School of Medicine, Cleveland
U of North Carolina School of Medicine, Chapel Hill
Children's Hospital, Boston
Cornell U Medical College, New York City
Northwestern U Medical School, Chicago
Washington U School of Medicine, St. Louis, Mo.
George Washington U, Washington, D.C.
State U of New York, School of Medicine, Stony Brook

NIAID vaccine evaluation units

U of Rochester, Rochester
U of Maryland, Baltimore
Johns Hopkins U, Baltimore
Marshall U, Huntington, W.Va.
Vanderbilt U, Nashville
Baylor College of Medicine, Houston

- Funding. How much is enough? The Institute of Medicine/NAS report says a billion dollars each for education and research should be sufficient. The Administration says that's too much right now. Congress leans toward those levels.
- The federal research effort. NIAID is the lead agency for the war on AIDS. It has quickly shot up from a small agency with a $300 million budget to one overseeing $600 million in research and drug and vaccine development for all infectious diseases in addition to AIDS. Is it up to the effort? New laboratories and clinical centers must be built. Scientists think the Administration is moving too slowly to bring them into operation.
- Overall AIDS research management. Should it be led by an AIDS "czar?" How tightly should it be "managed?" What are the areas of management needed? Would such management interfere with scientific creativity? Should an outside commission oversee any such effort?
- Drug development. Is government-industry-university effort coordinated well enough? At the moment the system of moving new chemical entities from the idea stage on up through characterization, evaluation, testing, and approval is still under development. Small research firms complain that their ideas are given insufficient hearing. Large companies think NIH is playing too heavy a role in drug development and are tired of hearing academic scientists question the industrial profit motive. Questions over secrecy and patent rights persist. Few understand the role the Food & Drug Administration should play in the development work.

Almost $1 billion ($962 million) has been spent on AIDS research and education since the disease was first funded specifically in 1983. But last month, the Senate approved a $946 million AIDS package, including $310 million for education efforts at CDC. Included separately are bills for testing.

Congress, however, is still learning how to respond legislatively to AIDS. It was only this year that AIDS became part of the authorization process, the mechanism by which Congress sets funding priorities area by area. Previously AIDS money came solely through the appropriations process, leaving distribution and priority setting pretty much to the agencies themselves. With authorization, Congress obtains open access to debate over important areas of emphasis.

The agency most involved in the basic decisions over funding is, of course, the Office of Management & Budget. There, a series of analyses of funding needs by the various agencies is continuing as the Administration's fiscal 1989 budget is being prepared for the President. "All this is going on while the fiscal 1988 budget is still unresolved, so we don't know what base to work from," says one OMB source. "Besides that," he says, "there are all kinds of authorizing bills that have not been acted on, including AIDS research, testing and confidentiality, drugs and AIDS, and abandoned infants."

The Administration is aiming for no more than a $791 million total AIDS figure for fiscal 1988. But Congress already is pushing for $1 billion. Requests from the relevant agencies for fiscal 1989 already total "well over" $1 billion, sources say.

"We're asking where the resources are going to come from to absorb the increases in AIDS money," says the OMB source. "We're looking at the morbidity and mortality of AIDS, and seeing that it's a lot less than other diseases. I don't think people are analytical enough yet; they're too emotional. We're in a situation now where we're dumping money into AIDS, where we're playing 'Can You Top This?' A cynical way of looking at it is that you can frighten people into starting a lot of base activities just by using the word AIDS."

OMB also says it is concerned with waste. "There's a lot of slop in the system that no one wants to deal with," he says. "No one really asks whether the programs are effective and whether they have goals. You never get those kinds of questions asked at Congressional appropriations hearings. I don't think the question of quality work will be dealt with analytically as long as AIDS continues without a cure."

Although the Administration at first was highly reluctant in face of pleas from scientists at CDC to open its purses in pursuit of AIDS treatment and cure, it is showing much less reluctance now. "We'll spend every dollar we can come up with on research for a cure, for vaccines, and for drugs to treat AIDS," says Gary L. Bauer, assistant to the President for domestic policy.

Bauer more recently has become deeply involved in the total battle against AIDS. Currently he is seeking a more precise understanding of the technical issues and the management strategies. Scientists are happy about that, though they continue to be put off by what they feel is Bauer's overly conservative rhetoric.

However, whether Bauer will agree with bills like the one sponsored by Edward M. Kennedy (D.-Mass.) is questionable. Kennedy calls for a network of officially designated AIDS research centers around the country, just as there are centers on cancer and heart disease. His legislation, moreover, would raise NIAID to an administrative level equal to that of NCI, which runs the war on cancer with a budget independent of centralized National Institutes of Health control.

NIAID's research strategy has six major components aimed at understanding:

- The natural history and epidemiology of the disease.
- The nature of the virus itself.
- The pathogenesis of AIDS.
- Drug therapy.
- Vaccine development.
- Rebuilding of the immune system.

The managerial aim is to integrate all those activities among industry, government, and academia and their diverse values and approaches. The effort is naturally very costly, so costly that enormous pressure exists to manage it well. Not only are new ideas needed in basic studies, but resources in the form of people and facilities are in immediate demand.

Nor is that research routine, especially the closer new ideas get to clinical applications. "Clinical trials don't fit easily into the context of routine clinical practice," says Jerry

Friedland of Montefiore Medical Center in New York City. "We need new facilities within institutions that are already taxed in terms of space and personnel. We need to recruit and train new personnel in an environment in which there are increasing recruitment difficulties for staff to work with AIDS patients." Within all that, he adds, is the need for systems for the collection of specimens, for information flow, for communication between investigators, for various medical services.

Adds Irving L. Weissman of Stanford University, "Although the research carried out to date has been of the highest quality, nowhere near the enormous talent pool available to work on this disease has, in fact, been effectively recruited."

At Stanford University, "and probably elsewhere," reports Weissman, there is no HIV containment facility available to qualified investigators who wish to follow their own lines of inquiry; no fully developed high containment animal facility to house mice or other [laboratory] animals; and no funds to build such facilities for common use by qualified investigators. Many outstanding groups continue to work in overcrowded and underequipped facilities."

Friedman and Weissman made their remarks at a lively two-day meeting on AIDS drug development and policies last August at the Institute of Medicine.

Even the idea of throwing money at AIDS—a concept OMB abhors—makes some sense. Says biochemist Paul Naylor of George Washington University: "We need a tripling of the research budget on AIDS to really ensure that truly new ideas will be funded. A doubling would allow funding of only further traditional ideas, since not enough of them are funded in normal budget years. A tripling is when the system really begins generating novel, nontraditional ideas. And that is what's beginning to happen now."

Federal AIDS funding has risen sharply since 1984

$ Millions	1984	1985	1986	1987	1988[a]
Public Health Service	$61	$109	$234	$494	$791
Federal medicaid share	0	0	130	210	375
Veterans Administration	6	12	24	30	44
Department of Defense	0	0	79	74	52

Note: Fiscal years. a Estimated. **Source:** Office of Management & Budget

To Weissman, the talent pool is available. But to Naylor there are shortages, for which he blames the government. "The number of scientists to study AIDS is limited by the number of people we trained 10 years ago," he says. "Over the years we have cut the number of scientists we've been training. One of the places to get scientists is from industry. But the biotechnology industry bought up tremendous numbers of academics who would have been in universities. Now, if you want to tap their abilities, you have to pay a fee to their companies so they can get a payback."

Misperceptions abound, depending on whether one is already a recipient of AIDS research funding, or hoping to get in. James D. Watson, director of Cold Spring Harbor Laboratory, charged NIH last August with closing off the field to those researchers on the outside. "You either become part of a formal agreement or you are not part of the effort," said Watson.

But Harvard University's William A. Haseltine, one of the early AIDS researchers, disagreed. Said Haseltine, "People have been invited in many, many times and have chosen not to enter. Scientific leadership has been lacking from our own traditional leaders in molecular biology, biochemistry, and virology."

Some scientists are complaining that the AIDS research effort, although necessary, has been undertaken at the expense of basic biomedical studies. Not only that, but research funds have shifted from so-called investigator-initiated research to studies that NIH suggests. NIH scientists sometimes find themselves the target of academic arrogance. "Most highly intelligent and accomplished investigators," commented one medical school researcher at the Institute of Medicine meeting, "do not wish to surrogate their own ideas and projects to those dictated and administered by other scientists—most of whom may not be as bright or as accomplished as the external investigator."

These are only a sampling of the complications involved in the AIDS crisis. OMB sources say the Administration is still far from organized for any such massive campaign against AIDS. "The AIDS war is more like Vietnam, where you can get mired in little battles," says one official. "Polio and measles required a vaccine; you could deal with that. But like in Vietnam, when you get to AIDS, you don't have to be very bright to just know the situation isn't going to be dealt with very easily."

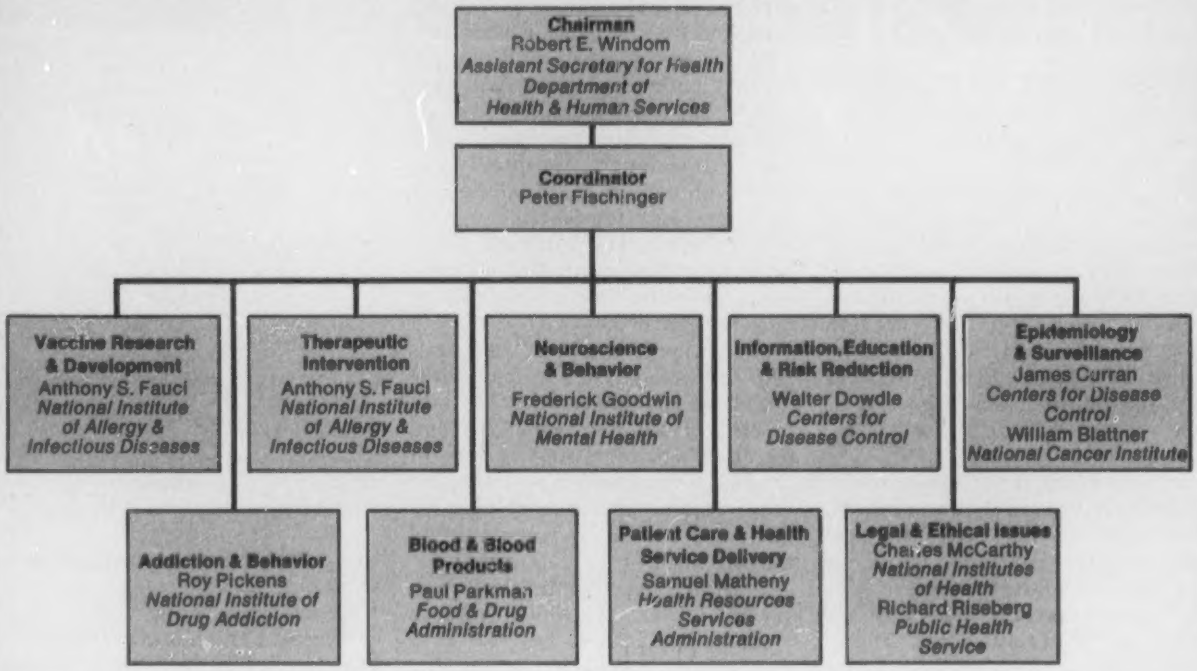
The Institute of Medicine's Thier agrees. Infectious diseases hadn't been considered anything near a crisis field with tragic and fascinating mysteries. The major infectious diseases had long been under control—until AIDS. Now battles need to be fought in guerillalike fashion against an often invisible enemy. No wonder Thier believes new coordinating ideas are needed.

"We have a tremendous health system in this country— the universities, the Public Health Service, and the pharmaceutical companies," he says. Health care funding is by and large adequate through medicare and other health insurance. The performances are superb. FDA approved the AIDS test in three months. AZT was approved in short order. Those groups were mobilized and are doing a terrific job.

"But still, there is no coordination among the Department of Health & Human Services, the Defense Department, and the departments of Education, of Justice, and of State. There needs to be someone processing information and looking at the gaps. The last thing I want is an administrative layer over NIH and CDC. Instead, I'd rather see a group saying things like 'Did you think of this line of research?' It would have the credibility to point out areas not being given enough attention."

That essentially is what the Institute of Medicine and NAS recommended and what the President's commission on HIV could well recommend when it makes its report

Public Health Service Task Force on AIDS attempts to coordinate AIDS effort


Chairman
Robert E. Windom
Assistant Secretary for Health
Department of
Health & Human Services
Coordinator
Peter Fischinger
Vaccine Research & Development
Anthony S. Fauci
National Institute of Allergy & Infectious Diseases
Therapeutic Intervention
Anthony S. Fauci
National Institute of Allergy & Infectious Diseases
Neuroscience & Behavior
Frederick Goodwin
National Institute of Mental Health
Information, Education & Risk Reduction
Walter Dowdle
Centers for Disease Control
Epidemiology & Surveillance
James Curran
Centers for Disease Control
William Blattner
National Cancer Institute
Addiction & Behavior
Roy Pickens
National Institute of Drug Addiction
Blood & Blood Products
Paul Parkman
Food & Drug Administration
Patient Care & Health Service Delivery
Samuel Matheny
Health Resources Services Administration
Legal & Ethical Issues
Charles McCarthy
National Institutes of Health
Richard Riseberg
Public Health Service

to President Reagan next June. Congress certainly is pushing for it in various bills. It is what the scientific community within the government was hoping Reagan would do immediately after the Institute of Medicine/NAS report came out. But to their disappointment, the President did nothing. The Office of Science & Technology Policy, in fact, made an attempt to inform the White House after a briefing by NIAID. But a list of recommendations brought to the East Wing by science adviser William R. Graham at the end of last year met only with silence.

Since then, Graham has been assigned no influential role in AIDS policy. An interagency group—the Federal Coordinating Committee on AIDS Information, Education, & Risk Reduction—which OSTP would normally head, is chaired instead by Department of Health & Human Services assistant secretary Robert Windom. Although Windom has spoken out as strongly as Surgeon General C. Everett Koop on the education/information issue, insiders say the committee he heads operates at too obscure a level to convince the President of the need for a White House consensus.

On the education issue, Thier thinks the scientific establishment has received a rude awakening on AIDS in that its best considered opinions were not heeded. "It's rare enough to have independently a consensus by the Institute of Medicine, the Public Health Service, and the American Medical Association on a set of policies. But to see them rejected as being too political is the awakening. The education effort has been bogged down because it is a sex and drug issue."

The testing recommendations met the same fate. Voluntary testing for large numbers of people was recommended by the panel, but top Administration sources and conservative members of Congress prefer a more mandatory approach. To Thier, the voluntary approach still makes very good sense. "Of the sites for voluntary testing that were set up, all have been oversubscribed. There were waiting lists of two to three months. And despite the fact that we cannot meet the demands for voluntary testing, people are still only talking about mandatory testing. The whole thing is bizarre."

Thier says an outside committee above the ideological battleground is absolutely needed to oversee the broad effort. "This is not an ideological process," he says. "It's a disease that's eating up a lot of people. It needs a mechanism to pull people together so that the public knows someone is in charge and is paying attention. The public doesn't know who to believe, who to trust."

Rochelle Diamond, an AIDS researcher at California Institute of Technology and spokesperson for the National Organization of Gay & Lesbian Scientists & Technical Professionals (NOGLSTP), says the group should be paying particular attention to coordinating the growing number of AIDS drug development laboratories. Too many are laboring in the dark, she believes. "Any coordinator," she says, "should be receiving information and disseminating it so that all the labs know who is doing what. We should be having more national meetings and having frank discussions about what is going on. Even today some people are complaining that the National Cancer Institute is not sending them the virus. And that brings up the issue of whether the distribution and cultivation of the virus should be controlled."

NIAID's Fauci says that such accusations are commonplace but wrong. And he is quick to defend the cancer institute's Robert Gallo, who has received most of the criticism. "Bob has heard about these accusations and he has compiled a list of people he has sent reagents to. It's easily an inch and a half thick. What I think is going on is, first, that you have personal antagonisms and rivalries between people in the field and, second, that he can be a difficult person to deal with. But reagents are not being withheld."

But more important than issues of personalities are the communication gaps between NIH and academic researchers. Fauci points out that misperceptions between NIH and researchers not yet fully involved in AIDS studies stem simply from unfamiliarity with the existing network and its structure. "The meetings and committees they say we don't have," he says, "have in actuality existed for months." As more scientists move into AIDS research, the perceptual gaps should close, he says.

Diamond herself admits things are getting better. "Although we need coordination, people are becoming aware. Congress knows we need the money. And we need to know that it gets to the right places and that the effort continues on a rational basis. But the work is slow and painful and we're losing a lot of lives. People are losing their friends."

One phenomenon that coordination could improve is the personal and professional interaction of scientists in the field. Right now there are difficulties here and there unrelated to the controversies that always seem to swirl around Gallo. Ian Brick of HEM Research Inc., which with Du Pont is developing the AIDS drug ampligen, speaks from the industry side. "A problem a lot of the companies are having," he says, "is the feeling of distrust toward the commercial people by those at NIH. They believe the companies have a lot of money and are in it to make money if they develop something. There's no trust between them. Most things come from commercial opportunities, and the bridge to that perception is not totally in place."

What isn't helping in this new interaction is the secrecy surrounding the best developments, stemming not so much from purely scientific competition but from the race to patent and commercialize new developments. Any successful treatment for AIDS, much less its cure, is an invention worth hundreds of millions of dollars.

"No question about it," says GWU's Naylor. "The sharing of data and ideas is significantly less than in other fields I've been in. I had never before seen such a lack of candor in discussing new ideas and the sharing of approaches. What we have is a series of close-mouthed relationships.

"Part of the problem is that people at NIH can take consulting fees from industry. Now they can have a relationship with a corporation, and that may not be so good an idea. Scientists at NIH aren't sharing ideas so much anymore, not even among themselves. For example, even to this day we haven't seen any data on the vaccine being developed by MicroGeneSys and NIAID. The scientists are not talking about it and their collaborators also are reluctant."

Now, Naylor says, relations among academia, NIH, and industry are an absolute necessity. "But as soon as you do that, you open the Pandora's box of secrecy and suspicion," he says. "Reagents are available only at a price. Antibodies to pieces of the virus are available only at a price, even though these agents were developed with the help of NIH scientists."

Fauci admits there is a problem. Competing university-industry-government consortia are now a reality. It's now standard operating procedure that scientists from a drug company, a university, and an NIH laboratory form a single developmental team. And such teams are competing. Fauci says information does tend to get withheld pending the filing of a patent. "Maybe ways can be found to accelerate the filing procedure," he says. "It's something the patent attorneys need to work out."

Thier: new coordinating ideas needed

In the end, though, a sense of compassion and ethics, whatever its likelihood, will have to be trusted to rule. "Drugs and devices to cure disease and relieve suffering should not be viewed as commodities," Montefiore's Friedland says, "but as a special sort of social good. Political economists, health policy makers, and industry are under a challenge to ensure that market forces do not deprive AIDS patients of potentially lifesaving resources."

Of all the aspects of the AIDS effort, drug development is the most frantic and confusing because it's so interconnected with the research effort. NIAID is essentially running the drug development effort, in a huge buildup of manpower and facilities, and thus operating in a mood of urgency and a continuing atmosphere of controversy.

NIAID is new at the game of drug development, however. NCI, on the other hand, has been clinically screening promising cancer chemotherapy agents for two decades through NIH's clinical center and a network of clinics around the country. So some of that NCI expertise is being lent to NIAID for the duration. For example, NCI is doing almost all of the in-vitro screening of new chemicals. And some of NCI's top drug experts have come over to NIAID to direct drug development.

Under NIAID, AIDS treatment evaluation units are being set up as funding continues to soar. Nineteen exist so far, with more to be established. A network of AIDS basic research centers will be established, similar to the national cancer centers spread around nationwide. Cooperative drug discovery groups and clinical studies groups also have been established. The institute is inviting researchers to submit applications for research and has to process applications and rule on new ideas as well as conduct its own research at the same time. NIAID is in the unique position of having to oversee basic research directed almost solely at therapy.

Naturally, many have criticisms of NIAID's efforts. "Right now it seems like they are just taking their own favorite drugs and forcing their network to look only at them and not do their own development work," says Naylor. "NCI has always allowed their collaborative networks to make their own decisions. But NIAID is much more centralized."

Paul Volberding of the University of California, San Francisco, another of the scientific AIDS pioneers, has related criticisms. He believes the movement of some important drugs into the research and evaluation system is being inhibited by current procedures. "There is a good deal of suspicion that scientific fads or commercial biases have a role in how drugs are developed," he pointed out at the Institute of Medicine meeting. "There is the feeling that clinical trials take too long and there is the common feeling that placebo trials are unethical, given the natural history of the virus."

Commercial biases derived from intense competition are indeed a reality and one that is difficult to get around given the current market system. "You can talk about drug development in a lot of ways," responded NIH's Wolfgang Joklik. "But as soon as someone out there identifies a new lead compound in any one area, the major fear that most companies have is that any other organization is going to 'derivatize' that compound and maybe beat them to the market with it. So patent rights aren't the only concern. It is secrecy in general that is raised."

Despite closer than ever collaboration between industry and academia in AIDS, the traditional conflicts persist. Joklik believes part of the problem lies in the "naiveté of academic institutions regarding drug development." He says the problem rises from several directions. "There are a lot of people who really think that the companies should pay through the nose up front. It is an unrealistic expectation. Related to that is the attitude of peer review. Many of the aspects of drug discovery and development are seen by the academic community as not being the most innovative, as being somewhat redundant at times. So getting through peer review presents a problem. To rectify that we have tried to get more people from industry on our review panels and to provide better education on what this program is about."

FDA comes under its share of pressure as well. Says Naylor: "To the investigator the major problem is that there is no clear policy guidance. You never know which side of the question FDA is going to come down on. Traditionally it was easy to go to Phase 1 of testing. What we feel is happening now is that FDA is adding an additional factor in trying to predict probability of the success of a procedure. That means that in a sense they are trying to weigh the efficacy without giving us the chance to show that it might be safe and effective. Also, we feel that FDA is not responding as quickly as we'd like to the expedited review process."

Some smaller companies think NIAID is showing favor to the large pharmaceutical firms. Comments a Capitol Hill staffer, "Small companies are saying that no matter what they do, they can't get NIAID's attention. The upshot is that we could be losing out on innovation by those small companies. NIH is setting things up by playing with the big kids and giving the cold shoulder to people with the 'harebrained' schemes."

And criticisms that the government is moving too slowly persist. "Those of us with AIDS are impatient," says Michael Callen of the People with AIDS Coalition. "We don't have the time to wait for the research systems already in place to move at the glacial pace for which bureaucracies are famous. The U.S. government's track record in terms of the treatments for AIDS is nothing short of scandalous."

Rochelle Diamond of NOGLSTP sees it all as a race against time. "My fear," she says, "is that if the AIDS numbers grow even more dramatically than they already have, and it spreads through the heterosexual population and there is still no cure, I'd expect you'd see more civilian concerns and demands for quarantine. At that point AIDS would no longer be so much a scientific issue as an ideological one."

Brick is sympathetic to all. "Everyone is beating a unique pathway through the woods with this effort," he says. "Of course we're all going to fumble and trip. No one's ever done this before."

So the pressure will continue as scientists like Fauci direct the war at a pace they consider maximum. Finding the AIDS cure is an exciting but painful chase. Organizational innovations are being developed. Hundreds of scientists have thrown themselves into it. Others, although willing, regret having left projects they were hoping to build careers on. Many feel AIDS research will contribute little truly basic knowledge to other fields.

The sniping continues even as scientists from academia, industry, and government display extraordinary teamwork at the expense of ego. At the same time, drug companies race to be first with the best treatment. There is tremendous potential for profit in successful products. Behind the chaos is an underlying order, which is to say a path toward a single overall goal.

Meanwhile, the public and the AIDS community have put science under an uncomfortable spotlight. The Whitehead Institute's David Baltimore, cochairman of the Institute of Medicine's AIDS panel, provided the trite but true bottom line to the situation last August. "The biomedical community," he said, "will be judged in the future by how we respond." ☐

The Business Response

Hundreds of concerns involved in development of vaccines, drugs, and diagnostic tests despite scientific, medical, and business uncertainties

Marc S. Reisch, C&EN New York

AIDS, like most human tragedies, has drawn the typical human response: a rallying around of those in a position to help. In the case of AIDS, this response has seen the buildup of a massive and what is becoming a reasonably well-coordinated cooperative effort to combat and control the disease. Business has been involved almost from the start.

In fact, AIDS is becoming a business opportunity for a significant number of venture capitalists and the small biotechnology firms they invest in, as well as for a host of pharmaceutical and large diversified companies. And drawing on either government funds or private capital, these businesses are working to develop the vaccines, drugs, and medical technology to handle those afflicted.

There is clearly great economic potential in AIDS. But that potential is very difficult to assess at this time for the longer term. This is primarily because of great uncertainty over the number of new cases of AIDS that will develop in the coming years, especially on a worldwide basis.

Data on the numbers of people who have been afflicted to date in this country are apparently quite precise. According to the Centers for Disease Control, the number of cases of full-blown AIDS in the U.S. is almost 45,000, with the number of deaths approaching 26,000.

What these numbers will grow to within the next few years is far less certain. CDC predicts a cumulative total of between 201,000 and 311,000 AIDS cases in the U.S. by 1991. It sets the most likely number at 270,000.

However, the former chief of epidemiology for CDC, Alexander D. Langmuir, believes that the AIDS epidemic will peak next year. Langmuir, who also founded CDC's Epidemic Intelligence Service, believes that AIDS will not spread generally to the heterosexual population in this country.

On the other hand, Surgeon General C. Everett Koop says that between 1 million and 1.5 million people currently are infected with the virus in this country. But he admits that number is speculative. It could be 400,000 or 4 million. Those estimates are based on very shaky evidence.

In another example of uncertainty, New York City officials have put the number of city residents infected with the AIDS virus as high as 600,000. But New York state officials estimate that there are only 400,000 infected persons in the entire state.

Global AIDS estimates also cover a wide range. For example, the World Health Organization says that 5 million to 10 million people are infected worldwide. It estimates 500,000 to 3 million people will develop the disease in the next five years.

According to a just-published study by management consultants Frost & Sullivan, more than 600 different companies in the U.S. are actively involved in programs linked to AIDS therapy or diagnostics. It estimates that the combined AIDS-related R&D expenditures of these companies exceed $500 million annually.

Frost & Sullivan's study predicts that sales of AIDS diagnostic tests will increase from about $35 million in 1985 to $65 million in 1987 and $135 million by 1989. It suggests that an erosion in selling prices after 1989 as a result of competition will shrink the market to $105 million by 1991. AIDS therapy products probably will increase from virtually nothing in 1985 to $964 million in 1991, the study predicts. Should the AIDS epidemic continue to spread rapidly, the study forecasts that sales of an AIDS vac-

Burroughs Wellcome worker inspects capsules containing zidovudine cine could exceed $1 billion annually.

Among the companies searching for an effective AIDS vaccine in this potentially enormous market, MicroGeneSys has received FDA approval for Phase 1 clinical trial for its version of an AIDS vaccine. According to MicroGeneSys president and chairman Frank Volvovitz, Phase 1 testing of the company's VaxSyn HIV-1 experimental vaccine began in September and is expected to last six months to a year. The National Institutes of Health, he says, continues to seek suitable volunteers to test the vaccine.

MicroGeneSys, he says, is owned by a small group of investors, though the company has no corporate partners to date. To finance its development of an AIDS vaccine as well as to finance other vaccine developments, Volvovitz says the company is considering an "arrangement" with a larger company, and would consider offering company stock to the public in the future, though the company has no immediate plans to do so.

A great deal, of course, would depend on MicroGeneSys' success in getting beyond clinical trials of its AIDS vaccine and receiving FDA approval. The attractiveness of the company as an investment would depend in large measure on not just approval, which is in no way guaranteed, but on public health officials' determination of population groups who would benefit from receiving the vaccine. That could cover, says Volvovitz, "a broad range of individuals from high-risk groups to the whole population. A lot depends on public health policy, which we are not a part of."

Burroughs Wellcome, the company that developed and received approval for zidovudine (AZT), the first drug which has been shown to prolong the lives of some AIDS patients, does not break out its R&D costs for the drug. However, a spokesman for the company says that the firm did spend $80 million in raw material purchases and capital improvements in gearing up for manufacture. The cost of the drug to patients is between $7000 and $10,000 a year.

Burroughs Wellcome also markets other drugs to treat AIDS opportunistic infections. These include, says a company spokeswoman, Zovirax, a treatment for herpes, and Daroprim, a treatment for toxoplasmosis. She says that the company is also working with α-interferon for possible application to AIDS patients.

Zidovudine was first drug shown to prolong the lives of some AIDS patients

A Hoffmann-La Roche spokeswoman would say only that the company spends $2 million daily worldwide on the research and development of new drugs, with an unspecified amount in the AIDS area. However, the company is investigating a compound called dideoxycytidine (DDC) as a potential AIDS treatment now in Phase 1 testing. Hoffmann-La Roche also is developing interleukin-2, a human protein for use in combination with other AIDS drugs, in partnership with Immunex. It is also testing its brand of α-interferon to treat Kaposi's sarcoma.

Imreg, a small New Orleans-based concern, has developed Imreg-1, a biologic developed from the white blood cells of healthy individuals. According to Arthur Gottlieb, chief executive officer of Imreg and also chairman of microbiology and immunology at Tulane University's medical school, Imreg-1 helps weakened T-helper cells function more normally. Now in Phase 3 testing in 150 patients, Imreg-1 has so far shown that it supports the immune system and has helped some patients gain weight.

Gottlieb says that Imreg has not financed its advancements with federal money of any sort. It has, he says, raised $15 million over the past six years, primarily from the sale of stock. He estimates that development costs for Imreg-1 to this point are $8 million, far lower than development costs associated with most new drugs, mostly because Imreg-1 is a biologic.

Among companies marketing diagnostic tests for AIDS, Du Pont estimates the U.S. market at $150 million annually. Only six months ago, says the Du Pont spokesman, people thought this market was only $40 million and set the world market at $150 million. This change is due largely to a sharp increase in the estimate of the number of medical institutions, federal agencies, state agencies, and other groups that eventually will start AIDS testing programs. Tests that Du Pont distributes include a DNA probe kit produced by Molecular Biosystems and a Western blot test from American Bionetics. Du Pont is developing its own second-generation recombinant protein tests.

Sue Brown, a marketing manager for Organon Teknika, a U.S. unit of the Dutch company Akzo, says the size of the market for diagnostics could easily be $150 million annually. Brown also says that the dollar

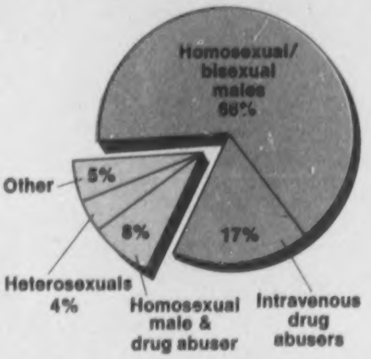
CDC constantly updates AIDS statistics

The Centers for Disease Control publishes weekly data on AIDS that offer fine detail of the distribution of the disease in this country. The bottom line, however, is the increasing numbers of new cases. These have grown from less than 300 in 1981 to more than 14,000 in 1986 and more than 8000 in the first half of this year.

Two thirds of the cases are homosexual males. One sixth are intravenous (IV) drug users, and another 8% are both homosexual males and IV drug abusers. Women make up 7% of all cases and 1% are children. What CDC describes as "heterosexual cases" make up 4% of the total to date. This category includes persons, both male and female, who have had heterosexual contact with a person with AIDS (or at high risk for AIDS) and persons born in countries in which heterosexual transmission is believed to play a major role. Almost one half, 49%, of females with AIDS are themselves IV drug users.

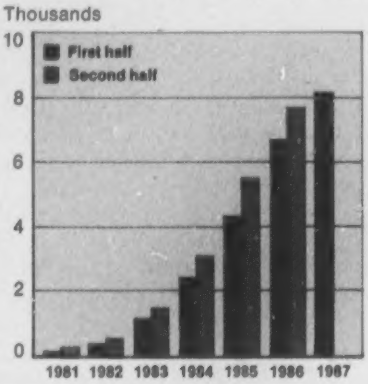
Only 5% of cases in the white population are drug abusers. In both the black and Hispanic populations, the figure is 35%. This approaches the male homosexual category of 40% for black, 49% for Hispanics.

Most are homosexual males, intravenous drug abusers



Total = 44,129 adult cases

Six-month figures show new cases of AIDS still growing



Source: Centers for Disease Control

figures are in constant flux as new tests and new clients enter the market. The company's own Bio-EnzaBead HIV ELISA test can cost anywhere between $1.50 and $4.00 per sample tested not including labor, she says. Its main market is the 20 million units of blood annually collected in the U.S.

Organon Teknika recently signed a contract with Epitope, a Beaverton, Ore., biotechnology company, to distribute Epitope's Western blot HIV test kit. Epitope estimates that the international market for such an AIDS test is $20 million annually. Epitope has not yet received FDA approval for sale of its kit. It values its contract with Organon Teknika at $3 million per year.

According to the American Association of Blood Banks, all units of blood annually collected by blood banks are tested for AIDS antibodies. The screening of units for AIDS virus as well as recently added testing for hepatitis virus has added $1.00 or so to the unit cost of red blood cells, says an association spokeswoman. Units cost between $30 and $100, depending on the part of the country where they are sold.

Although a number of small companies continue to be involved in developing products for the AIDS market, many larger companies have worked out financial arrangements with much smaller concerns to get a start in the AIDS product markets. Those companies include Du Pont (with Centocor, Cistron, Molecular Biosystems, and others), Baxter-Travenol (with Cambridge Medical Tech, Ribi Immunochem, Biogen, and others), Hoffmann-La Roche (with Genentech, Immunex, and Centocor), and American Cyanamid (with Cytogen, Hybritech, Celltech, and others).

Eastman Kodak, for instance, has developed a distribution business in AIDS-related diagnostics and distributes an ELISA test developed by Cellular Products and Cetus. In addition, it plans to offer a gene amplication reference service using Cellular Products technology beginning in 1988, according to John G. Knowles, Eastman Kodak product manager of biological diagnostics.

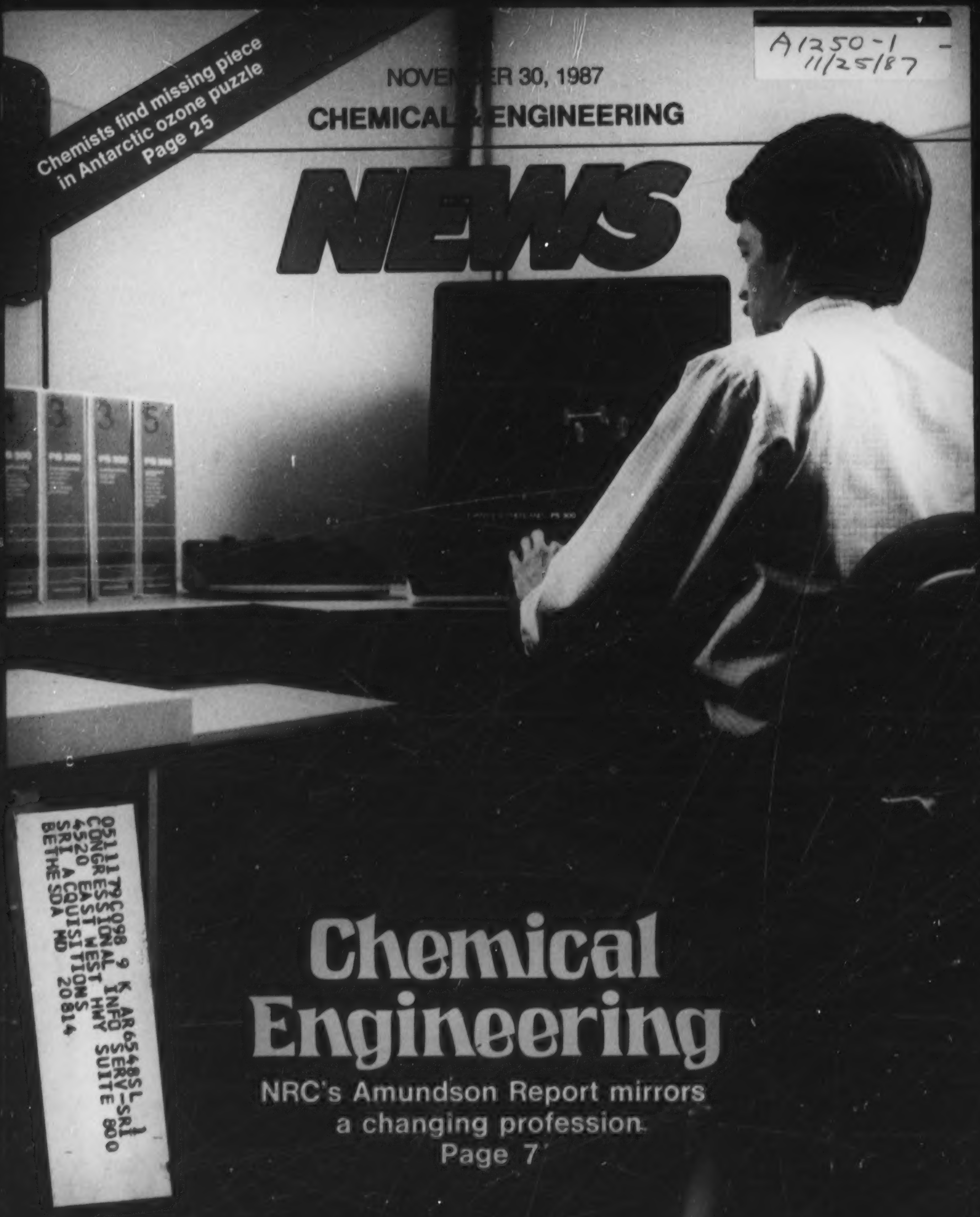
The trend of smaller companies linking forces with larger companies with deep pockets is likely to continue. Because of the recent decline in the stock market, it has become less likely that small, financially shaky biotechnology companies will be able to raise the large amounts of money they need in the hope of developing products for an uncertain AIDS market. "Those people who are willing to risk the market will put their money into safer stocks," says David Webber, a biotechnology industry analyst with Jeffrey Casdin & Co. "It's a dark period now for biotechnology stocks. Collaborations with large concerns will keep some of them afloat," he says.

Certain product markets have grown as unintended beneficiaries of the AIDS scare. Hospital support staff, emergency medical workers, police, and dental hygienists have started to wear latex rubber gloves for protection from the AIDS virus. Industry sources say that manufacturers expect demand to double for latex gloves within the next three to four years.

Condom sales also have benefited from the AIDS scare. Most of the 12% growth in condom sales between July 1986 and July 1987 can be attributed to the Surgeon General's recommendation that condoms be used to reduce the risk of AIDS transmission, says a spokesman for Carter-Wallace, manufacturer of Trojan condoms. Partly as a result of the scare, too, condoms are now vended by supermarkets and convenience store outlets, helping increase unit sales to 365 million at a value of $200 million annually. □

A1250-1
11/25/87

NOVEMBER 30, 1987
CHEMICAL & ENGINEERING
NEWS



Chemists find missing piece in Antarctic ozone puzzle
Page 25

Chemical Engineering

NRC's Amundson Report mirrors a changing profession
Page 7

0511179C098 9 K AR6548SL
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 65, Number 48
CENEAR 65 (48) 1–56
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
NOVEMBER 30, 1987

News of the Week

- **After two-year delay, Indian government publishes results of medical studies on effects of methyl isocyanate on Bhopal disaster victims.** **Page 4**
- **Testing by Kerr-McGee of fertilizer generated from treated radioactive wastes in Gore, Okla., is being monitored closely by both the company and local residents.** **Page 5**
- **Permissible formaldehyde exposure limits are to be reduced by OSHA after years of petitioning by unions.** **Page 5**
- **New journal on conducting ethical research is due for publication early next year.** **Page 6**
- **New plant biotechnology research center in Albany, Calif., will concentrate on study of agriculturally important plant genes.** **Page 6**

Business

Plastics packaging shows potential for continued growth, but industry is forewarned about concerns over solid waste disposal. **Page 15**

Government

Word to the wise from Chemical Manufacturers Association workshop: reduce waste now to limit pollution, improve public image, and avoid strictures of regulation. **Page 21**

American Medical Association takes ethical stand that physicians cannot refuse to treat AIDS virus-infected patients. **Page 22**

Science

Key puzzle of Antarctic ozone depletion is solved by two studies that link reactions on ice surfaces of cloud particles to creation of chlorine species that deplete ozone. **Page 25**

Books

"Fluorine: The First Hundred Years" covers the history of fluorine chemistry as well as recent advances in the field. **Page 28**

ACS News

Chemical industry mergers, acquisitions, and restructuring continue to have a marked impact on employment of chemists. **Page 35**

Cover: Photo courtesy of Evans & Sutherland

News Focus

National Research Council Committee, chaired by Neal R. Amundson, is set to issue report on research needs and opportunities at the frontiers of chemical engineering that reflects a profession in flux. **Page 7**

Letters 2

Concentrates

Business 13
Government 20
Science/Technology 24

The Departments

ACS Comment 33
Awards 39
Newscripts 56

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Wilbert C. Lepkowski, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Joyce A. Richards (Head), Anne Riesberg (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve

© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

Two periodic tables

SIR: I could not resist the temptation to make a tongue-in-check observation concerning the possibility of a revised format for the periodic table.

During a basic organic chemistry course many years ago, we were exposed to the various systems of nomenclature. It was pointed out that the International Union of Pure & Applied Chemistry had brought sanity to the situation by introducing a highly organized method of naming compounds. When I asked why the other methods were still being used, now that IUPAC had straightened things out, I was told that for a while multiple systems would have to be used because the older nomenclature was deeply rooted in the literature and many older chemists had been trained in its use. What would be the guess as to how long future, first-year chemistry students will have to learn two periodic tables, for similar reasons? **Charles Feldmann**
Cincinnati

Methanol to gasoline?

SIR: A. M. Souby's letter (C&EN, Aug. 17, page 3) was written with the breadth of perspective of a laser—a very narrow and uncompromising beam.

Souby's bias for gasoline comes from his long career with the great company, Exxon, whose dominant interest is hydrocarbon fuels. Another Exxon engineer, E. E. David, with a much broader background and perspective, noted (*Chem. Eng. Prog.*, Nov. 1981, page 22) that among its other recognized advantages, methanol is "the lowest cost liquid fuel available from coal," and in automobiles has "fewer emission problems."

Souby evidently thinks he developed—but doesn't detail—new polymers of methanol in deposits in his outboard motor. He did use methanol in this because of its well-known advantages, including much greater efficiency and horsepower from a given engine. However, he does qualify his lack of proof of new solids or semisolids produced from methanol when he considers the possibility that "much of these [polymer deposits] resulted from the castor oil [lubricant used] rather than the methanol."

He did recognize methanol's much greater efficiency with higher compression engines, and reports, "I don't know what the compression ratio was, but in a cylinder of 15 cu in the optimum volume remaining at the top of stroke [outboard motor], as I remember it, was about 30 cc though some racers reduced it to as low as 27 cc."

His methanol fuel was doctored with 5% each of benzene, toluene, and xylene, also some ether—and castor oil as a lubricant. After water was allowed to get in, he condemned methanol for a cloudy mixture; but after many years of consideration, "I am not sure now whether the cloudiness was the result of the hydrocarbons or of the castor oil coming out of solution because of the dilution with water." His latter judgment is correct—hydrocarbons alone would have formed a clean separate layer, castor oil is a partial emulsifier, not found in auto tanks. Nevertheless, he just assumed phase separation like the polymeric sludge would be caused by the methanol.

For some time he used "a lot of gasohol" in his automobiles and then some time after returning to using gasoline, he encountered "carburetor problems" that were "blamed on the use [many miles before] of fuels containing ethanol."

A person's prejudice cannot be changed, however absent may be any scientific, engineering, or quantitative studies or thinking. As to racing cars, personal interviews with drivers at the Indy 500 show that methanol has been the only fuel used in that race for decades because drivers insist that it is by far the safest fuel, least fire hazard; it is by far the most efficient fuel; it allows smaller, lighter engines and cars; and it gives longer life to these very expensive, very overworked engines.

One considerable advantage, not of particular concern to racing drivers, is that the exhaust is almost pollution free—and methanol is thus being specified for use in buses in many cities. Its high antiknock eliminates use of poisonous lead, or benzene, toluene, and xylene, which cause cancer. This BTX at up to 45% in our "super unleaded" gasoline adds 12 to 15 cents per gal cost at the pump, wastes 5% of the possible product, and some say threatens a greater hazard than lead by causing cancers and other ailments.

After 1 million miles of a test [Energy Sources Conference, *Am. Soc. Mech. Eng.*, **8**, 91 (1987)] of some 15 cars of different foreign and domestic makes, using 87 octane gasoline against a blend of 10% methanol in the same gasoline, both fuels in the same usage in the same cars displayed the following:

Packaging Continues as Strong Growth Market for Plastics

Despite rosy outlook, concern is increasing over problem of solid waste disposal and pressure in some communities to ban all plastics packaging

Patricia L. Layman, C&EN London

Good growth lies ahead for plastics in packaging, but pressure on the packaging industry will intensify because of increasing concerns about waste disposal and biodegradation.

That's the conclusion reached at a plastics packaging conference held during Interplas '87, an international plastics and rubber exhibition, in Birmingham, England, earlier this month. The conference was sponsored by the Plastics & Rubber Institute, based in London.

Certainly a message of growth in the packaging industry would be good news to the industry's suppliers of plastics and nonplastics alike. As Geoffrey Barrett, a principal with Corporate Development Consultants Ltd. (CDC) in Bristol, England, pointed out, pulp and paper-making chemicals for packaging, in value terms, account for more than 3.5 million metric tons of material, worth about $2 billion. Other packaging materials include petrochemical feedstocks for polymers; chlorine and soda ash for polyvinyl chloride and glass; and various specialty supplies, such as solvents, resins and polymers, and pigments and dyes, for the formulation of adhesives, surface coatings, lacquers, and printing inks.

In fact, he adds, packaging is the largest single market for thermoplastics—"depending on which country you study, between 30 and 40% of thermoplastics consumption. Taking Western Europe as a whole, packaging accounts for 42% of thermoplastic consumption, and this percentage will remain little changed over the next decade."

The amount will fall slightly in Western Europe from 42% in 1985 to slightly more than 39% in 1995, as other end-use markets increase their consumption of thermoplastics. But packaging will still consume more than twice the next-largest single end use, building and construction, at 17%, Barrett says.

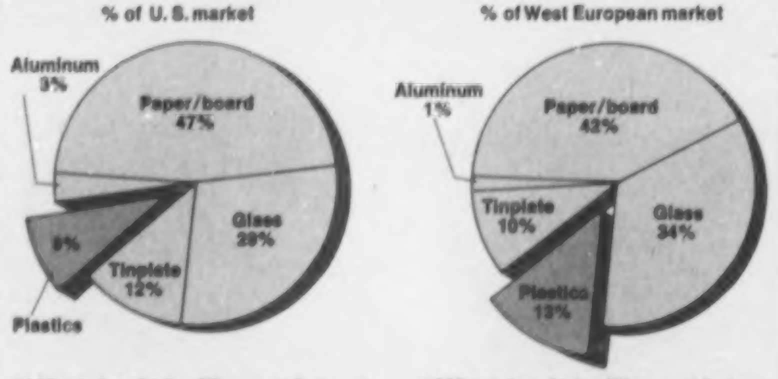
Earlier studies indicate that the U.S. consumes twice as much packaging material per capita as Western Europe, with a higher proportion of paper and board, tinplate, and aluminum, and a smaller proportion of glass or plastics, he says. There are also significant national differences among countries in Western Europe. Figures pulled together by CDC from various trade associations in West Germany, the U.K., France, and Italy indicate that for 1984, the most recent year available, West Germany has the highest proportion of tinplate packaging. The U.K. has the lowest percentage consumption of aluminum, and Italy the highest. And France, perhaps because of its high consumption of wine and mineral water, has the highest proportion of glass packaging.

Polyethylene terephthalate (PET) is the success story of the decade. Virtually unknown five years ago as a packaging form in Western Europe, it now accounts for more than 1 billion packs, mainly in Belgium, Italy, Luxembourg, the Netherlands, and the U.K., Barrett notes.

Some of the advantages of plastics for packaging, he predicts, will influence growth. For example, as food technologists develop alternatives to retorting for food processing, or as industry develops polymers or containers with controlled barrier properties, plastics for food and beverage containers will replace tinplate cans and glass jars and bottles.

Paper and board packaging probably will be least affected, he adds, particularly with the continued growth of cartons for liquids, at the

Plastics bigger portion of packaging in Europe than in U.S.



1985 total = 54.0 million metric tons[a]

1985 total = 41.6 million metric tons

a C&EN estimate. **Source:** Corporate Development Consultants Ltd.

Local governments consider bans on plastic packaging

As landfill sites at a number of U.S. municipalities reach capacity, at least two local governments are considering a ban of plastic food wrapping.

The principal target of packaging laws now under consideration in New York's Suffolk County and Berkeley, Calif., is the polystyrene "clam shell" package that many fast-food restaurants use to wrap hamburgers, chicken, and other fare.

In addition, a New York state official, Richard M. Kessel, executive director of the State Consumer Protection Board, recently made public a letter he wrote to McDonald's chairman Fred L. Turner, asking that the giant food chain "discontinue" the use of polystyrene packaging "and instead expand its use of paper products made from recycled material."

Nearly everyone agrees that a waste disposal crisis exists. The case of the Mobro, a barge filled with 3100 tons of garbage that traveled up and down the Eastern seaboard this summer in search of a site at which it could legally dispose of its cargo, illustrates the crisis at hand.

But Ken Lane, assistant director for state government affairs for the Society of the Plastics Industry (SPI), says that disposable plastic food packaging is a very small part of a much larger waste problem. At least, he says, polystyrene packaging remains inert in a landfill and does not leach poisonous chemicals into groundwater as so-called biodegradable paper packaging does.

SPI publishes statistics that show that polystyrene packaging, including "clam shells," cups, plates, and other items, is the largest single end-use category for polystyrene. It accounted for more than 25%, or 1.1 billion lb, of all polystyrene used last year in the U.S.

Dow Chemical, a major supplier of polystyrene resins to packaging manufacturers, suggests that what municipalities need are comprehensive solid waste programs. Karl Kamena, Dow's director of government affairs, suggests that incinerating solid wastes and recovering the energy thus produced is one option. Recycling where it makes economic sense is another option. "It is pure foolishness," he says, to rely on degradable packaging. He agrees with Lane that degradable plastics and paper may form more harmful by-products and pose a greater danger to the environment than inert landfilled plastic waste.

Kamena points out that landfills "are designed to handle nondegradable waste. It is the degradable material that causes the problem." But he is not insensitive to the fact that landfill space is either unavailable or only available at a high cost in some areas of the country. He notes that landfill costs for communities in some areas of the U.S. have risen from $4.00 to $100 a ton.

Today the cost of burning waste to recover energy amounts to $35 a ton after the initial investment in a burn

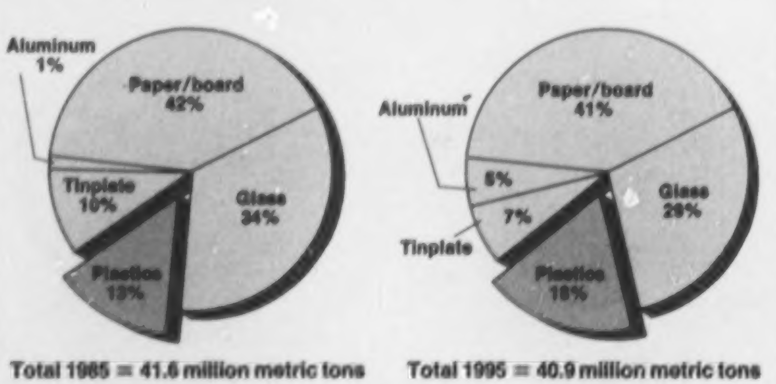
---

expense of glass. And aluminum will grow largely at the expense of tinplate in beverage cans. In the U.S., 90% of beverage cans are aluminum; in Western Europe, however, aluminum accounts for only 30%.

Meanwhile, there is certainly room for growth in plastics. More than 85% of all grocery products are still sold in standard forms of traditional packaging—glass, metal, and cardboard, says Sheila Clark, managing director of U.K.-based Packaging Innovation Group Ltd.

For packaging companies, she says, "plastics materials offer the chance to create the pack with a difference." That's important for the food industry, she adds, because the business as a whole is not expanding, so food companies must rely on increasing their market share at the expense of competitors. Innovating packaging is one way to do that, particularly when the packaging is "user friendly."

Plastics use in packaging to grow in Europe



Total 1985 = 41.6 million metric tons

Total 1995 = 40.9 million metric tons

Source: Corporate Development Consultants Ltd.

One such case is the ketchup squeeze bottles, introduced in Western Europe in 1986, following the introduction of bottles with high barrier properties, important for products with few or no preservatives. And, as the market for barrier bottles increases, so too will the demand for other improvements, she suggests—for example, the clarity of the pack or its ability to withstand wider temperature ranges, thereby enabling substitution of plastics for glass jars containing pasteurized products, or packs that can go directly from freezer to oven without distortion. The popularity of microwave ovens has already encouraged the growth of plastic packs.

That's not to say the potential is unlimited, however. Clark points out that when PET was first introduced, "it gave marketing managers the opportunity to sell twice the volume of product for relatively little increase in selling space. Two-L bottles grew to 3-L ones, which again increased purchase by 50%—but where does it go from there? Apart from value for money, the facility, says Kamena. At that price, waste incineration could provide a more attractive long-term alternative to landfill. Two years ago, he says, 5% of municipal waste was burned to recover energy; today, about 10% of municipal wastes are burned. The only real impediment to more widespread use of garbage incineration is concern over dioxin emission levels. "We need a national standard on permissible levels of dioxin emission," Kamena says. The Environmental Protection Agency is currently establishing such levels, he adds.

However, New York's Suffolk County has gone ahead with its proposed plastic packaging ban, revising and expanding the bill (C&EN Aug. 24, page 7). According to Jay Schoenfeld, an aid to legislator Steven Engelbright, who first proposed the bill, revisions now include certain plastic wrapping bans for fruit, cheese, and meat.

Schoenfeld says that the bill still has more than the majority support it needs to pass. It is also unlikely to meet opposition from the recently elected county executive, Patrick Halpin, who as a county legislator sponsored Suffolk's pacesetting bottle return law years ago. The bill is likely to come up for a vote in December, he says.

Though New York state's legislature is not currently considering a ban of plastic food packaging, Kessel has indicated that such legislation could be proposed. However, a proposal is before the state legislature to tax nonrecyclable packaging. It would put a tax of up to 3 cents on nonrecyclable packaging for a given number of packaging units. Potentially recyclable materials would receive a 1-cent credit, and packaging made from recycled material an additional 1-cent credit. The tax would be waived for material meeting both criteria.

In fairness to fast-food vendor McDonald's, observers note the company is examining the packaging issue. It recently agreed to phase out the use of polystyrene foam packaging produced with chlorofluorocarbons, compounds believed to deplete atmospheric ozone. Competitor Burger King advertises that it uses biodegradable paper in its packaging.

In a separate issue affecting plastics disposal, the U.S. Senate's Environment & Public Works Committee approved a bill recently that would prohibit the disposal of plastic wastes in U.S. water and by U.S. ships anywhere. The bill, sponsored by Sen. Frank R. Lautenberg (D.-N.J.), implements the provisions of an international treaty recently passed by the Senate—the International Convention for the Prevention of Pollution from Ships.

Sen. Lautenberg's bill provides for a penalty of up to $50,000 for offenders and up to five years in prison. The bill also would require a study of the feasibility of recycling and production of biodegradable plastics.

Marc Reisch, New York

3-L pack has few other benefits," and 4- to 5-L packs even less.

Those 2- or 3-L packs have been highly important for the beverage industry, says Ian Roberts, of the packaging department of Coca-Cola Northern Europe, based in London. "In the past 10 years, the growth in the use of plastics for primary packages has been phenomenal."

But there are some significant challenges ahead that must be confronted if that record is to be maintained, he says, and if plastic packaging is going to continue its contribution to the growth of carbonated beverages.

"Perhaps the single most important way in which the plastics industry can help is to broaden the scope of our understanding of what plastics are, what they can do, and how we can realize their full potential to the benefit of our markets," Roberts says. Many involved in bottling have "only a very superficial knowledge of plastics technology, and as a result, pay scant attention to the full range of performance potential that plastics offer."

Furthermore, there is definitely a need for the plastics industry to define properties in terms that packagers understand. "Raw material data sheets do a very good job of defining basic properties, but often contain very little that is of any meaning or value to the package end user," Roberts adds.

The increased contact between plastics producer and package user is going to become even more important for the beverage industry, he suggests, because plastics conversion, unlike glass or can manufacture, lends itself very well to integration of package manufacture and filling. A number of beverage firms have already installed in-house package manufacturing facilities and this trend is likely to continue.

Despite all the good news about growth potential and market innovations and challenges, however, the problem of solid-waste disposal lurked in the background of the conference. For example, one of the session chairmen cited with concern one of the recent "Letters from America" broadcast by Alistair Cooke on the British Broadcasting Co., which lauded recent legislation in his hometown on the U.S.'s West Coast, to ban all plastics packaging. Most people at the conference felt that such a ban would be unworkable and eventually would be rescinded. And, of course, there were thoughts that the ban was in a part of the U.S. that is perceived as customarily doing odd things. But clearly the action shook them.

Coca-Cola's Roberts, for one, brought the issue squarely out front. His industry is particularly visible—and vulnerable. As he noted, "It is an unfortunate and uncomfortable fact of life that where the environmental lobby focuses on the impact of packaging on the environment, the frontline is usually beverage containers. So far in the U.K., we have felt very little practical effect of the onslaught of adverse opinion on nonreusable beverage packaging, but unless we adopt a much more positive stance we are all in danger of having our abilities to innovate effectively curtailed.

"If we fail to confront this issue, external controls will be applied to our activities, limiting our freedom to meet market demand, and ultimately stifling the innovation and growth which we seek for our businesses," he says. ☐

Competitive Moves by Industry Still Tough on Some Chemists

Michael Heylin, C&EN Washington

Many of the mergers, acquisitions, and other business restructurings that have characterized the chemical enterprise in recent years may have been justified in terms of assuring corporate survival in an increasingly competitive world. They have also helped bring about a more lean and mean chemical industry. But they are continuing to have a marked impact on the employment situation for chemists and chemical engineers, especially more experienced ones.

The details of some of these impacts are apparent in the latest report by the American Chemical Society's Committee on Professional Relations (CPR) on multiple terminations. The report covers 10 mass firings—which occurred between March 1984 and June 1987—involving about 250 chemists and chemical engineers. All but one involved chemists with more than 10 years of service.

The largest of the cutbacks, involving 99 chemical professionals at Owens-Corning Fiberglas' technical center at Granville, Ohio, resulted from a potential takeover. The loss of 16 chemical jobs at AMF Inc. followed the acquisition of the firm by Minstar.

Major terminations at Dow Chemical and Goodyear Tire & Rubber, each affecting 31 chemical professionals, involved early retirement programs, as did the termination of 13 at the National Bureau of Standards. The other terminations covered in the report involved 17 chemical professionals at Kraft Inc., 17 at Miles Laboratories, 12 at H. G. Pars Pharmaceutical Laboratories, nine at Kaiser Aluminum & Chemical, and three at Los Alamos National Laboratory.

CPR defines a multiple termination as a situation in which the employment of three or more chemists or chemical engineers is terminated within a six-month period for reasons other than cause, completion of a contract, or continuing evidence of previously documented inadequate performance. All terminees do not have to have worked at the same location.

The new report is the 26th in a

Employer compliance with ACS guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans	Rehire privileges
Kraft, Duracell Research Center (Needham, Mass.)	17	□	▨	□	□	□	▨	■
Dow Chemical, Texas Applied Science & Technology Laboratories (Freeport, Tex.)	31	▨	▨	□	□	▨	□	■
Goodyear Tire & Rubber (Akron, Ohio)	31	■	■	□	□	■	□	□
Kaiser Aluminum & Chemical (Pleasanton, Calif.)	9	□	■	□	□	■	▨	■
National Bureau of Standards (Gaithersburg, Md.)	13	□	■	▨	□	■	▨	▨
Owens-Corning Fiberglas (Granville, Ohio)	99	▨	□	□	□	▨	*	■

These employers provided no information; hence, all ratings based on terminee responses

AMF/Minstar (Stamford, Conn.)	16	▨	▨	□	□	■	▨	■
U. S. Department of Energy/ University of California, Los Alamos National Laboratory (Los Alamos, N. M.)	3	□	▨	▨	□	■	▨	■
Miles Laboratories (Elkhart, Ind.)	17	▨	▨	▨	□	■	▨	■
H. G. Pars Pharmaceutical Laboratories (Cambridge, Mass.)	12	■	■	■	*	▨	■	■

* No information from any source.

□ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice–less than two weeks.
- Assistance–no assistance rendered.
- Severance pay–less than one week per year of service.
- Employee service–more than 40% of terminees had 10 or more years of service.
- Protection plans–no continuation of protection plans.

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after 10 years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination at same rate of contribution as before. Employee would have additional 31-day grace period.

Rehire privileges. Rehire privileges should be carefully explained to terminees.

series of such studies dating back to 1974. They compare the performance of employers having terminations with seven standards contained in ACS's Professional Employment Guidelines (PEG). These standards are concerned with employee service, severance pay, rehire privileges, pension vesting, assistance in obtaining new employment, extension of health and other protection plans, and advance notice.

CPR judges if employers have either complied with (or exceeded), violated, or "substantially" violated each standard. For the more than 230 terminations investigated in the 26 reports, standards were complied with (or exceeded) 43% of the time. They were violated 40% of time and "substantially" violated 17%. For the latest report, the compliance rate was 35%. This was a sharp downturn from the previous report, which showed a 59% compliance rate (C&EN, June 15, page 28).

In the latest report no employer complied with more than four of the seven standards. Miles Laboratories failed to meet six of them. H. G. Pars Pharmaceutical violated five of them "substantially."

In investigating mass terminations, CPR's Subcommittee on Professional Standards seeks data from both employers and terminees. About two thirds of employers have been willing to supply such data; six of the 10 did so for the latest report. Information from terminees is mostly obtained with the help of ACS local sections. The California, Columbus, and Northeastern sections were involved in data gathering for the latest report.

CPR asks individual society members to send information on terminations with which they are personally familiar to American Chemical Society, Office of Professional Relations, 1155—16th St., N.W., Washington, D.C. 20036. This office will provide, on request, copies of all CPR termination reports and a summary list of terminations over the past decade.

Of particular concern to CPR is the continued attrition of experienced employees. This situation is getting worse. The PEG guidelines state that those with a minimum of 10 years' service should not be terminated, except for continued incompetence, completion of a contract, or cause. But such long-service employees have been terminated in 42 of the 45 terminations covered in the past five CPR reports. For all 26 reports, this standard has been complied with only 22% of the time.

An employer is deemed by CPR to have "substantially" violated the employee service standard if 40% or more of those terminated had 10 or more years of service. This has happened in 40% of the cases investigated to date, including six of the 10 covered by the latest report.

Another standard that is not well complied with is the one for severance pay. This calls for a minimum of two weeks' pay for each year of service. In the latest report only Owens-Corning Fiberglas complied. Four of the other nine employers were in substantial violation by averaging less than one week of pay for each year of service. For all 26 CPR reports, this standard has been complied with only 19% of the time. However, compliance with this standard has been gradually improving. For the past 10 reports it has averaged 30%.

The lowest long-term average compliance, 17%, is for the standard stating that rehire privileges will be carefully explained to terminees. In most cases, including nine of 10 in the latest report, this apparently is just not done. Eight of the employers investigated in the latest report state that their policies do not require the rehiring of those terminated before new employees are recruited.

On the other end of the scale of compliance is the standard calling for full pension vesting after 10 years of service. In recent years, this has almost always been complied with. Compliance rate of all 26 reports is 86%.

The standard stating that terminees should be helped in finding new jobs, either by internal transfer or outside, has been reasonably well complied with in recent years, including in six of the 10 cases in the latest report. Long-term compliance is 70%.

Compliance with the standard concerning extension of employee protection plans beyond the termination date has averaged 49% for all 26 reports. But this has been declining in recent years. Only 17 of the employers in the 62 mass terminations examined in the last seven reports have complied. In the latest report only two employers, Dow and Goodyear, met this standard.

Four of the employers investigated in the latest report met the standard calling for advance notice of a minimum of four weeks. This is in line with long-term compliance that averages 39%. □

1988 dues bill

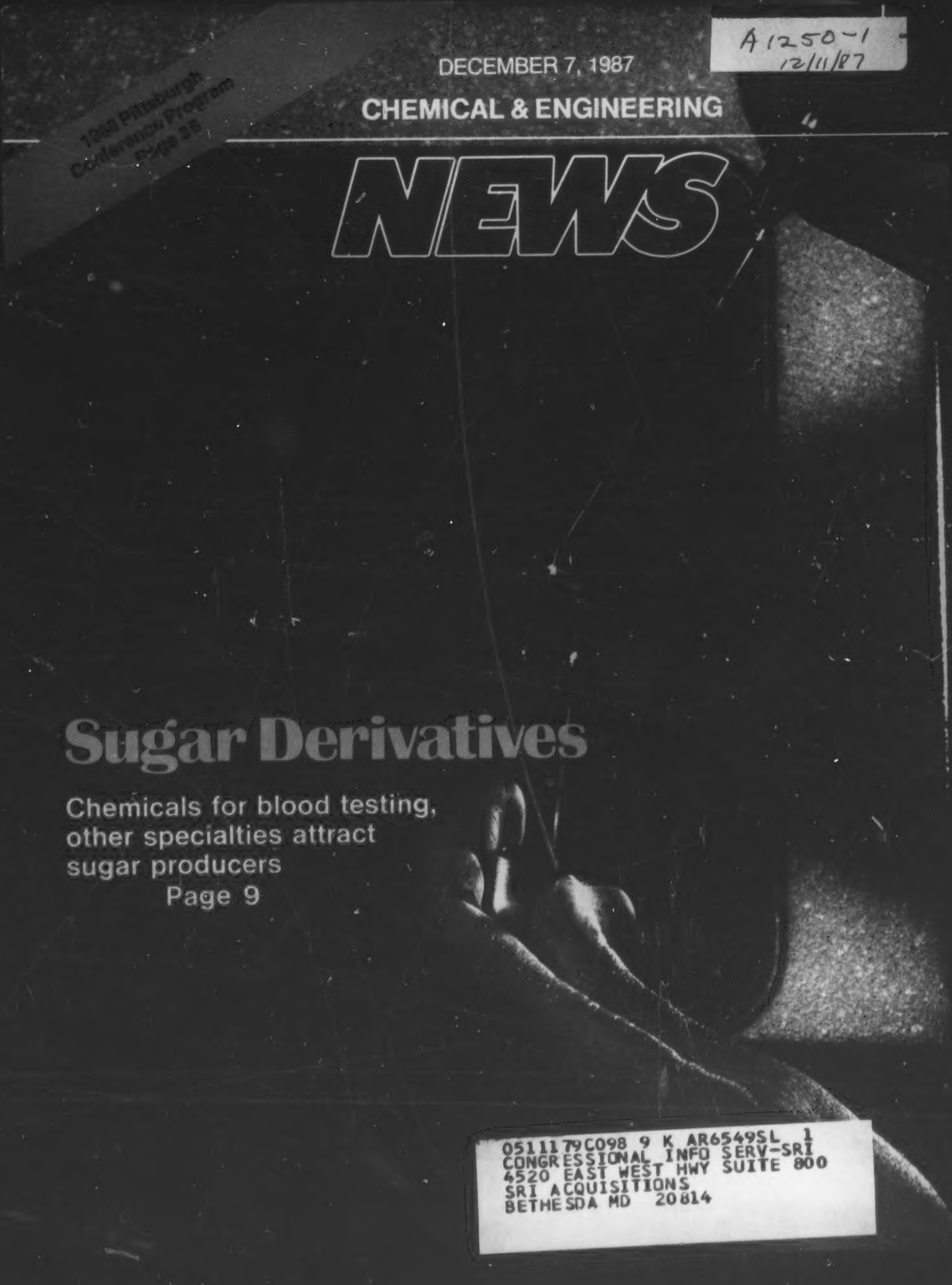
If you have not received your 1988 dues bill or have questions about your bill, please call (614) 421-3776. To charge your payment by phone, call toll free (800) 227-5558, or in the Washington, D.C., area, call (202) 872-8070. Questions on the ACS credit policy should be directed to Earl Klinefelter, head of the Membership Activities Department, at (202) 872-4372.

A1250-1
12/11/87

DECEMBER 7, 1987

CHEMICAL & ENGINEERING NEWS

1988 Pittsburgh
Conference Program
Page 35



Sugar Derivatives

Chemicals for blood testing,
other specialties attract
sugar producers
Page 9

0511179C098 9 K AR6549SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 65, Number 49
CENEAR 65 (49) 1–60
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

DECEMBER 7, 1987

News of the Week

- **Improved relationships with U.S. scientific, technological, and industrial communities will be sought during U.S.-Soviet summit this week in Washington. Page 4**
- **Top Montedison executives' battle over chairmanship may entail major changes in the Milan-based chemical company. Page 5**
- **Proposed EPA regulations would cut production of chlorofluorocarbons in U.S. 50% by 1998 and restrict use. Page 5**
- **EPA program that monitors toxic chemicals in human tissues may end this year because of budget constraints. Page 6**

Cover: Performance of blood analysis. Photo by Jim Olive/Uniphoto Picture Agency

Letters 2

Concentrates
Business 7
Government 14
Science/Technology 18

The Departments
ACS News 34
Newscripts 60

Government

New nuclear waste bill calls for selection of permanent repository site by 1989, construction of monitored retrievable storage facility. **Page 15**

EPA opposes indoor air quality bill supported by environmentalists, says it's too expensive and provides no new regulatory authority. **Page 16**

Science

Coulomb explosion technique is valuable direct method for determining structure of molecular ions. **Page 25**

Methyl group in tricyclic orthoamide has carbon-hydrogen bonds virtually eclipsed with three adjacent single bonds. **Page 28**

Evidence accumulates on three-electron covalent bond that may have wide implications in organic chemical reactivity. **Page 32**

Meetings

1988 Pittsburgh Conference miniprogram includes symposium sessions, registration and other information. **Page 35**

Business

Worldwide surplus of sugar is leading many sugar producers to look into commercialization of third- and fourth-generation derivatives, search for new uses in specialty chemical markets. Page 9

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Wilbert C. Lepkowski, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Joyce A. Richards (Head), Anne Riesberg (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve

© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 59)

LETTERS

Fragmentation fluorescence spectrometry techniques

SIR: Certainly there is nothing new under the sun, but to be honest, it almost seems that there is nothing new in the chemical literature either. An article on new strategies in spectroscopy (C&EN, Sept. 21, page 45) featured Earl Wehry's presentation at the ACS New Orleans meeting. Briefly put, Wehry's group uses an intense ultraviolet laser to dissociate molecules yielding small electronically excited fragments. The fragment fluorescence pattern is shown to characterize the parent. The method is powerful, but it is neither new nor unpublished.

Our group at Howard explicitly demonstrated this and related methods [Halpern, J. B., Jackson, W. M., McCrary, V. R., "Multiphoton sequential photodissociative excitation: a new method of remote atmospheric sensing," *Appl. Opt.*, **18**, 590 (1979); and Halpern, J. B., Koker, E. B., Jackson, W. M., "Fluorescence spectrometry with photodissociative excitation of ammonia and hydrazine," *Anal. Chem.*, **55**, 2000 (1983)]. We were the first to show how efficient excimer lasers were for the photodissociative excitation of fragment emission from a variety of species in 1978 [Jackson, W. M., Halpern, J. B., Lin, C. S., "Multiphoton photodissociative excitation," *Chem. Phys. Letts.*, **55**, 254 (1978)]. Unique signature curves were shown for several polyatomic molecules.

The article in *Analytical Chemistry* showed how the NH emission from excimer laser photodissociation of ammonia could be used for quantitative remote sensing. Although a fixed frequency source was used, we pointed out the advantages of tunability.

The UV laser method depends on multiphoton processes. Therefore, the signature and sensitivity are intensity dependent. Flux-dependent photodissociative excitation is a better analytical tool. In the work described in *Analytical Chemistry*, a Kr resonance lamp was used to detect, quantitate, and distinguish between ammonia and hydrazine.

The correspondence between our statements and the report of Ward Worthy about Wehry's work is eerie. Worthy writes: "Wehry noted that luminescence methods, despite their advantages, have one major shortcoming: Most compounds simply don't fluoresce . . . at levels high enough to be analytically useful. . . . Wehry and his coworkers have been using a different approach, fragmentation fluorescence spectrometry [FFS], based on the fact that many large, nonluminescent molecules can be broken up into smaller, intensely luminescent fragments. Common luminescence fragments include OH, NH, CH, CN," and so on.

In our paper, one reads: "Standard fluorescence techniques are limited for analytical purposes by the relatively small number of substances which emit light. . . . In general, only fluorescence from diatomic and triatomic molecules . . . may be dispersed sufficiently to be rotationally and vibrationally analyzed. . . . In the last 15 years a large body of work has shown that small excited fragments are produced when polyatomic molecules are dissociated by vacuum ultraviolet. . . . The pattern of the fluorescence from the photodissociately excited molecule is idiosyncratic, depending on both the identity of the parent and the energy of the light."

By the way, we referred to the method as photodissociative fluorescence signature analysis (PFSA) eight years ago. I am glad that the idea has found recognition, and I do believe that it is a powerful addition to the analytical toolchest, but we would appreciate a share of the credit for our published work.

Joshua B. Halpern
Department of Chemistry
Howard University, Washington, D.C.

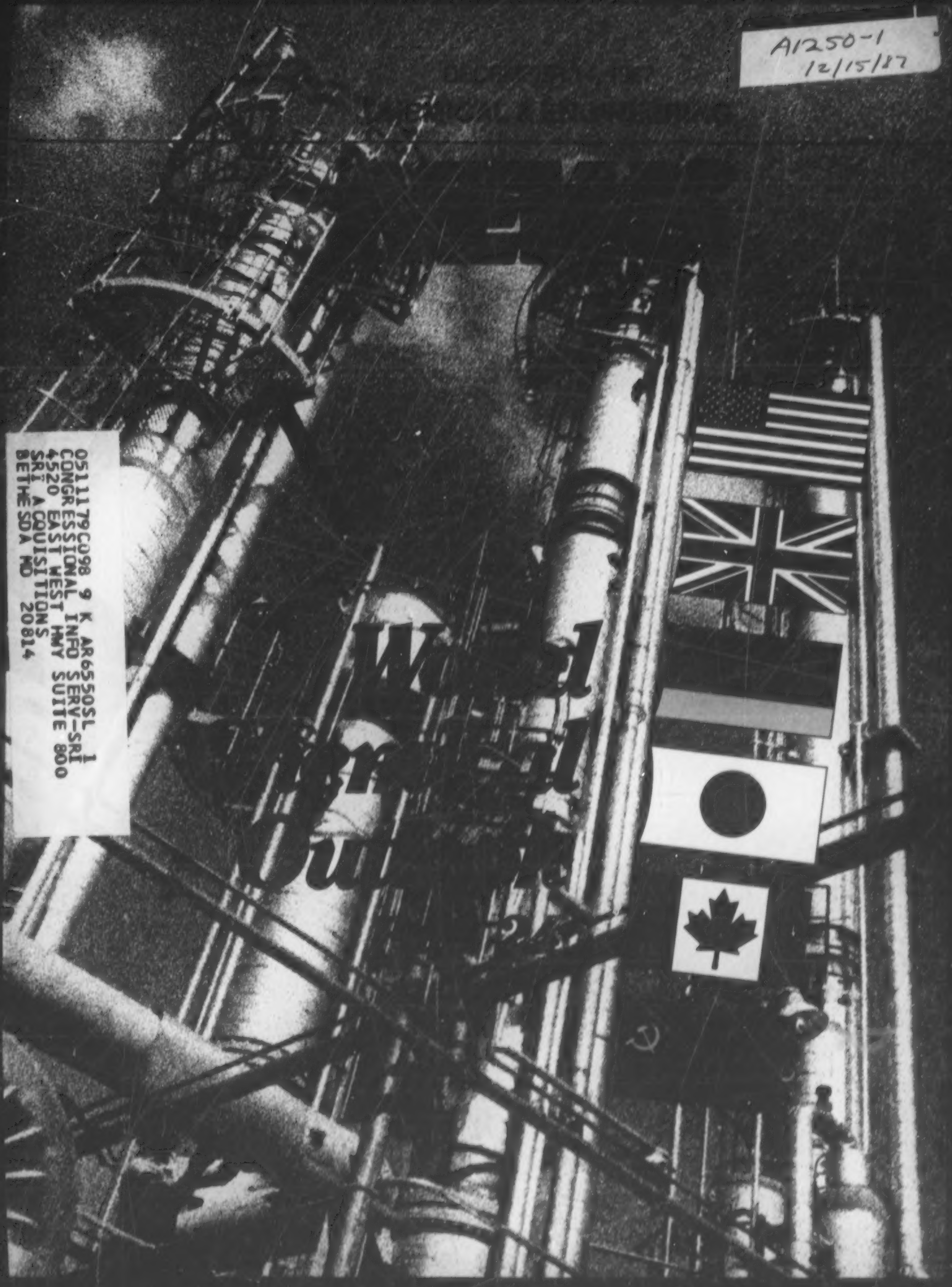
Wehry's response: We certainly have no objection whatsoever to Professor Halpern and his coworkers seeking and receiving appropriate credit for their work in detection of nonfluorescent molecules via fragment fluorescence. However, his inference that our published work contains "nothing new," being merely duplicative of his, is not correct.

For example, the published work of

Corrections

- Nov. 16, page 12: In the table, Air Products & Chemicals sales for the first nine months of 1987 were $1598.4 million, not $2132.2 million; earnings were $121.2 million, not $159.7 million.
- Nov. 23, page 22: The legend on the map is incorrect. It should have indicated that the AIDS virus HIV-1 is predominant in the large area of central Africa, whereas HIV-2 appears more frequently in the West African countries of Senegal, Gambia, and Guinea: both HIV-1 and HIV-2 appear in the West African countries of Ivory Coast and Burkina Faso.

A1250-1
12/15/87



World Chemical Outlook

05111179C098 9 K AR65505L 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 65, Number 50
CENEAR 65 (50) 1–66
ISSN 0009-2347

DECEMBER 14, 1987

News of the Week

- **At the recent U.S.-Soviet summit in Washington, D.C., scientists from both countries met in an effort to expand cooperation in scientific and economic areas. Page 4**
- **National Coalition for Science & Technology, a lobby group that focused on the nuts and bolts of issues affecting scientists, closes its doors six years after it was founded. Page 5**
- **ACS Board, meeting in Ohio, votes to set next National Chemistry Day for 1989, reelects Ernest Eliel as chairman, and approves 1988 budget. Page 5**
- **NAS symposium on science of nutrition examines field's current status and attempts to identify future research, training directions. Page 6**
- **For fifth year in a row, plastics industry registers new record highs for plastics sales, production. Page 6**

Letters 2
Editor's Page 3

Concentrates

Business 7
Government 11
Science/Technology 16

The Departments

Books 48
ACS Comment 51
ACS News 52
People 64
Newscripts 66

Business

As demand for polyvinyl chloride exceeds supply, inventories shrink, prices increase, and producers move to expand capacity. **Page 9**

Government

National Groundwater Research Act requires three government agencies to conduct coordinated research program; wording of Clean Water Act influences Supreme Court ruling on citizen suit; House committee urges repeal of a section of the pesticide law to shift burden of dealing with suspended pesticides from EPA to manufacturer. **Page 12**

Science

New STN International software eases text and graphics searches on its databases; summer research program for disabled undergraduates aims to provide them better access to science-related careers. **Page 19**

Technology

Digital Equipment program is designed to assist labs in developing integrated multivendor computing environment; modular spectrometer enables chemists to adapt instrument to current and future needs; NRC panel stresses need for new space technologies; molecular biology exhibit opens at Smithsonian Institution. **Page 20**

Special Report

Worldwide chemical companies reap benefits of restructuring and slashed production capacity as prices rise and productivity and profitability increase. Page 24

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Wilbert C. Lepkowski, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Joyce A. Richards (Head), Anne Riesberg (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve
© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 65)

LETTERS

Chiral recognition system

SIR: We at Illinois were gratified at the coverage given to the work of William Pirkle and his group in the recent article "Progress Made in Synthesizing Enzyme Mimics" (C&EN, Oct. 19, page 30). The article was well written and technically quite accurate. Your readers might be interested to know that the chiral recognition mechanism advanced to account for the deracemization study described in the article has been supported by rather elegant intermolecular nuclear Overhauser effect studies conducted by Thomas C. Pochapsky while he was a graduate student in the Pirkle group. Pochapsky developed the chiral recognition system, which led to the deracemization studies. This work has recently appeared in the *Journal of the American Chemical Society*, **109**, 5975 (1987).

Gary B. Schuster
Professor of Chemistry
University of Illinois, Urbana-Champaign

Environmental chemistry

SIR: The article on "Education for New Technology" (Oct. 26, page 34) was excellent, suggesting as it does that our field needs to expand at the fringes to encompass hot new areas such as materials, solid-state chemistry, and biochemistry. Chemistry is an old and conservative field that has been slow to react to new opportunities.

One fringe area the article did not mention is environmental chemistry. Our department at the University of Maryland has had a very successful graduate program in environmental chemistry for the past 15 years involving both atmospheric and water research. The problems involved in the field are some of the largest issues facing society: e.g., global climate change, destruction of the ozone layer, and the control of toxic wastes.

Although environmental chemistry does not usually involve breakthroughs in the fundamentals of chemistry, it demands highly sophisticated applications of chemistry and other disciplines. Furthermore, environmental chemistry has driven great improvements in our knowledge of elementary chemical reactions, modeling of complex chemical systems, the development of highly sensitive analytical methods, and the application of multivariate statistical methods to chemical problems, a field now called "chemometrics." Although chemistry plays a central role in most environmental problems, academic research and teaching in the field are rarely found in chemistry departments. Instead they are often located in departments such as civil engineering, atmospheric sciences, environmental sciences, or environmental engineering. This is most unfortunate, as the insights of people trained as chemists are usually needed for a thorough understanding of the problems.

Glen E. Gordon
Department of Chemistry and Biochemistry
University of Maryland

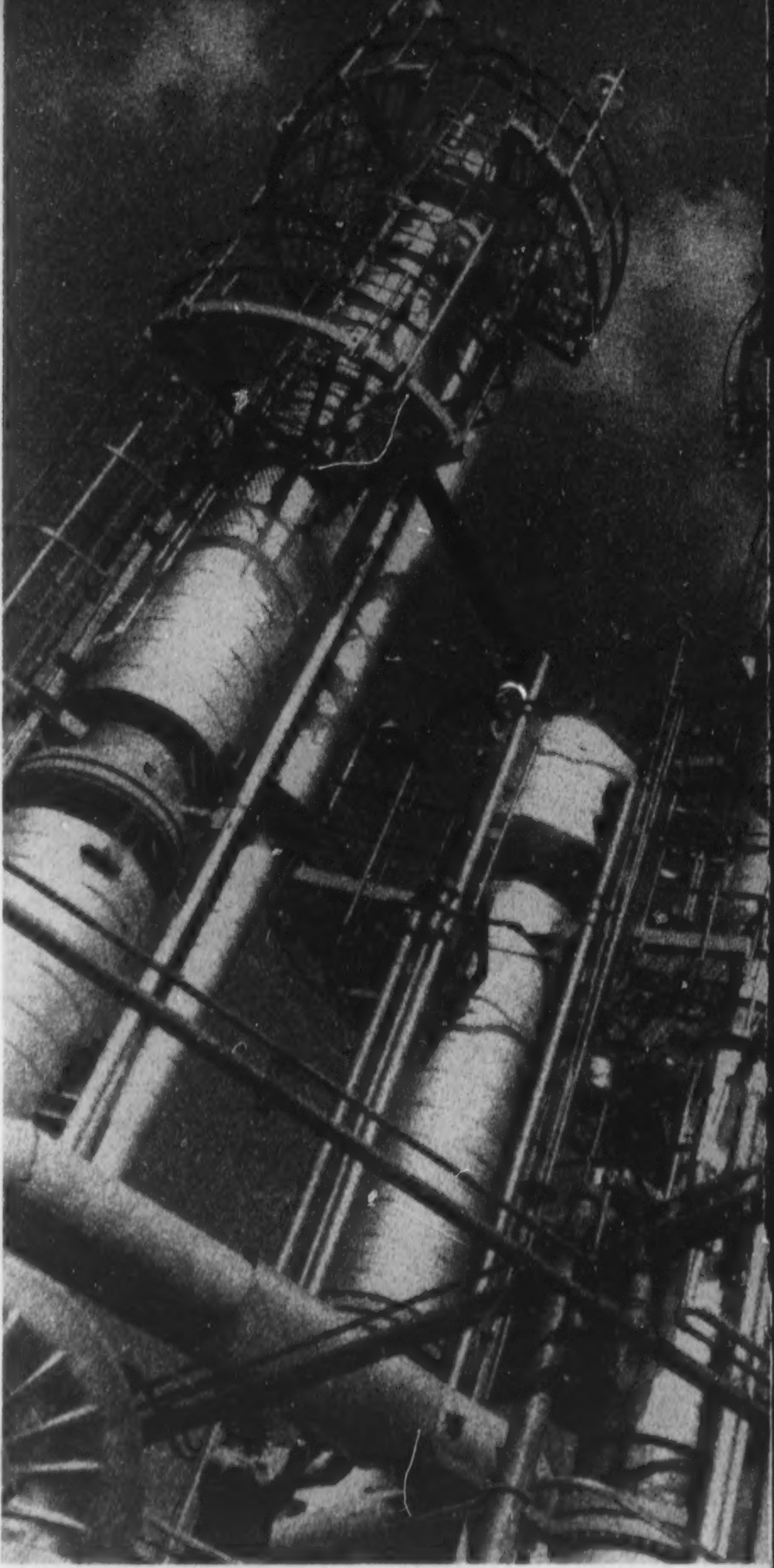
Polyene cyclizations

SIR: This is in regards to your article on polyene cyclizations (C&EN, Oct. 19, page 34). Like many others, I have been inspired by the brilliant chemistry that encompasses the polyene cyclization, developed under the inspiring leadership of William S. Johnson, Stanford University. Their recent observations that cation-stabilizing auxiliary improves the yields of the polyene cyclization reaction [*J. Am. Chem. Soc.*, **109**, 5852 (1987)] have led Johnson's group to speculate on the enzymic mechanism involving biological carbocations as reaction intermediates. A proposal has thus been advanced that the transition state analogs of the biological carbocations should be potent inhibitors of enzyme catalyzed reactions.

It should be heartening for the readers of C&EN to note that in a series of communications, it has already been demonstrated that a biological carbocation can be efficiently mimicked by an ammonium function, including N-oxides [Narula, A. S., Benveniste, P., et al., *J. Am. Chem. Soc.*, **103**, 2408 (1981); *Biochem. Soc. Trans.*, **11**, 537 (1983); *J. Biol. Chem.*, **259**, 15215 (1984); *Lipids*, **21**, 52 (1986)]. These studies have led to the development of some of the most potent inhibitors of plant sterol biosynthesis and squalene-2, 3-epoxy-cyclase.

These studies have been extended by others to devise transition-state analog inhibitors of farnesyl pyrophosphate-squalene synthetase [Poulter, C. D., *J. Am. Chem. Soc.*, **104**, 7376 (1984)] and isopentenyl pyrophosphate isomerase [Abeles, R. H., et al., *J. Am. Chem. Soc.*, **107**, 4078 (1985)]. More recently, a summary of the inhibitors of squalene-2, 3-epoxide cyclase devised by exploiting the above concepts has also appeared [Cattel, L., et al., *Lipids*, **21**, 31 (1986)].

Acharan S. Narula
Duke University Medical Center
Durham, N.C.



What a difference four or five years can make.

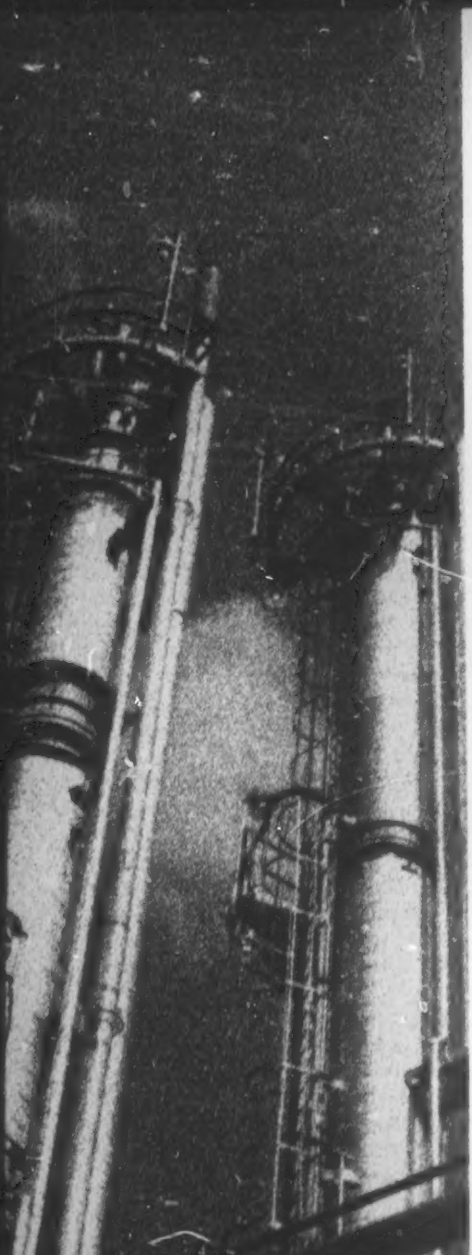
Reporting on the outlook for the world's chemical industry at the end of 1982, "widespread malaise" were the words that C&EN used. "Production of chemicals has been cut back drastically," we reported at that time, and plant capacity is "far in excess of any foreseeable demand. Producers increasingly find themselves strapped financially."

Since then, however, chemical companies throughout the industrialized Western World have inflicted a massive revamping upon themselves. It has not been without pain. Tens of thousands of jobs have been wiped out. Hundreds of millions of dollars worth of operating assets have been jettisoned. Research and investment programs have been radically reshaped.

Demand for chemicals has increased in the past five years. As a result, output of industrial chemicals and synthetic materials in the U.S. this year is more than 40% higher than in 1982. And in the major chemical-producing countries of Western Europe and in Japan, chemical output is up 15 to 30%, as well.

That's hardly exceptional growth, by any means. But with production capacity slashed, in many key product areas plants now are being pushed to their design limits and producers are reaping the rewards—in higher prices, higher productivity, and increased profitability—that stem from a seller's market.

In a relatively slow-growing global economy, next year's harvest may be less bountiful. But the world's chemical industry now seems to have its house in good enough order that it will be able to withstand an economic slump, should it occur, better than it could in the early 1980s.



World Chemical Outlook

United States 26

Foreign Trade 29

Western Europe 32

Japan 40

Canada 43

U.S.S.R./Eastern Europe 45

Mexico 47

United States

Profits up sharply as producers reap benefits of restructuring

A much slimmed down chemical industry is running many of its plants full out to meet current demand

David M. Kiefer, C&EN Washington

This autumn has witnessed chaotic turmoil in U.S. investment and currency exchange markets. Deep and recalcitrant deficits continue to sorely beset both the federal budget and the U.S. balance of foreign trade. Auto sales are slumping and new housing starts are on a decline. Consumer confidence may be ebbing, and, in the wake of the recent debacle on Wall Street, predictions of impending recession, although still not the consensus among economists, are becoming more common.

So who is crying all the way to the bank? U.S. chemical producers, that's who.

This year, producers of basic industrial chemicals, plastics, and fibers will boost their sales at least 10% to about $90 billion (exclusive of sales of foreign subsidiaries), thanks to increased demand both at home and abroad and to higher selling prices. For the broader chemicals and allied products industry, sales will show a slightly stronger gain of 11 to 12%.

But it is the industry's profitability that really is on a roll. Net income for makers of basic chemicals and synthetic materials will surge 40% or even a bit more in 1987, to about $7 billion. That's a new high by a long shot. Profit margins are higher than at any time in the past decade as cutbacks in overhead and improved operating efficiency permit many companies to carry more of each dollar of revenue down to the bottom line. Earnings for the overall chemicals and allied products industry, meanwhile, will increase almost as much to about $18 billion.

Several factors are responsible for this year's favorable performance by the chemical industry. Strong consumer demand throughout the year has benefited many chemical end markets, including packaging, apparel, appliances, furniture, and electronics. As a result, output of plastics and fibers and of the chemical intermediates that are needed to make them has risen steadily throughout the year. For the year as a whole, production of industrial chemicals and synthetic materials will be about 9% higher than in 1986. And for the overall chemicals and allied products industry the increase in output will be about 6%. Both figures are considerably higher than the 3% increase in production likely this year for U.S. industry as a whole.

Meanwhile, for the second year in a row, the chemical industry is harvesting the fruits of the drastic reorganization that it imposed upon its operations in recent years, especially in 1985. The chronic excess capacity, slow market growth, depressed prices, cutthroat competition, and consequent lackluster earnings that plagued chemical companies throughout the early 1980s led to widespread programs for repositioning, rationalization, and restructuring. Marginally profitable and money-losing businesses were shut down or sold off. Staffs were cut to the bone. And many major companies shifted their emphasis away from their traditional commodity chemical lines to focus more on the development of specialty products. These, presumably, will be less prone to competition and more likely to garner a favorable return on investment. Monsanto, for one, has slashed its investment in commodity petrochemicals from about a quarter of its total assets in 1980 to only 3% now.

The combination of increased output and scaled back plant capacity has greatly enhanced the industry's productivity. For the first time in several years, too, producers of many chemical products are enjoying a sellers' market and operating their facilities full out. In this year's third quarter, according to Federal Reserve Board statistics, plant utilization in the chemical industry rose to 84% of capacity, up from 80% a year earlier. The industry's operating rate has not been higher since 1974, and just five years ago it was as low as 68%.

In some notable old-line product areas, moreover, plants now are operating even closer to their upper limit. Chlorine and caustic soda producers, for example, were running their plants at about 90% of capacity—or over 100% of "effective" capacity, allowing for plants temporarily shut down—this fall, according to the Chlorine Institute. Output of the two workhorse coproducts will be up 4 to 6% this year to the highest level since 1980, largely because of strong demand from producers of vinyl chloride and other organic chemicals and from the pulp and paper industry. At the same time, however, with some 20 plants shuttered during the 1980s, chlor-alkali producers are making do with about 13% less capacity than they had in 1982. As a result, supplies are tight and suppliers, for a change, now are thinking of expanding rather than shrinking capacity.

Ethylene producers, too, are hard pressed to keep customers supplied. Output this year will rise only a modest 3%, more because of capacity restraints than slow growth in demand. Current U.S. capacity of about 35 million lb per-year is operating at well over 90%, so that further growth will be dependent on debottlenecking present units, upgrading their technology, or restarting plants now mothballed.

Makers of a number of other basic petrochemicals, especially monomers for making plastics, are similarly hard pressed to keep customers satisfied. And in the plastics industry itself, with total production for the first nine months of 1987 up 10% to 36 billion lb, producers are having little problem in finding a buyer for every pound they can turn out. Even man-made fiber plants are humming close to capacity.

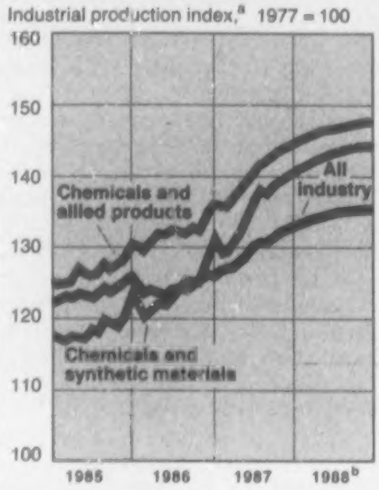
All of which leave chemical companies, for a change, sitting in the catbird seat. Selling prices reflect this. Producer prices for industrial chemicals, after having sagged steeply last year in response to the sharp decline in the cost of petroleum-based feedstocks, have rebounded sharply throughout most of 1987. Although for the year as a whole they will be up, on average, just about 4%, right now they stand 7 to 8% higher than at the end of 1986. Plastics prices, meanwhile, are more than 15% higher. Feedstocks also cost more this year, but chemical makers are now in a good position to pass such increases, and more, along to their customers.

The continuing slump in the value of the U.S. dollar relative to major foreign currencies has been yet another fundamental plus for the chemical industry. For one thing, earnings from the industry's far-flung operations abroad are magnified when translated into dollars at increasingly favorable exchange rates. Even more important now, however, U.S. chemicals are gaining a strong price advantage in overseas markets when competing with products made in Europe or Japan. As a result, $26 billion worth of U.S.-made chemicals will be sold to foreign customers this year, 15% more than in 1986, a hefty $3.4 billion increase over 1986 to U.S. companies' sales volume. At the same time, of course, the weak dollar has made U.S. chemical companies look like cheap and tempting targets to foreign companies interested in expanding in the big U.S. market.

All in all, increased exports, higher sales prices, strong demand, and improved efficiency have provided the U.S. chemical industry with the leverage, this year and last, to put its finances in better shape than at any time in more than a decade. Can the string be extended to three years?

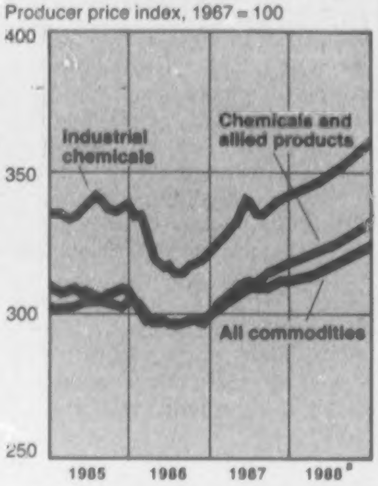
That depends, of course, on the continued health of the overall U.S. economy. Economists and business analysts generally have been moderately optimistic for 1988. Most are looking for gross national product, after adjustment for inflation, to increase about 1.5 to 2.5%—a rate of growth that probably will be slightly below this year's. And the consensus is that, although the rate of ex-

Growth in production is likely to taper off . . .



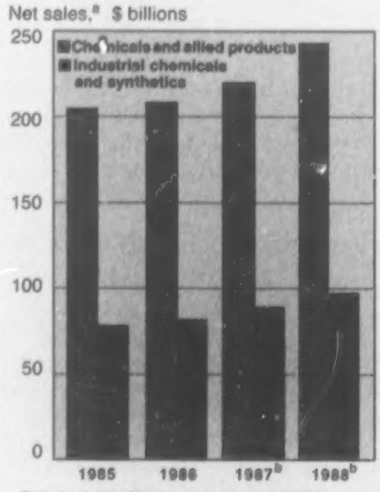
a Seasonally adjusted. b C&EN estimates.
Source: Federal Reserve Board

. . . but prices of many chemicals are climbing . . .



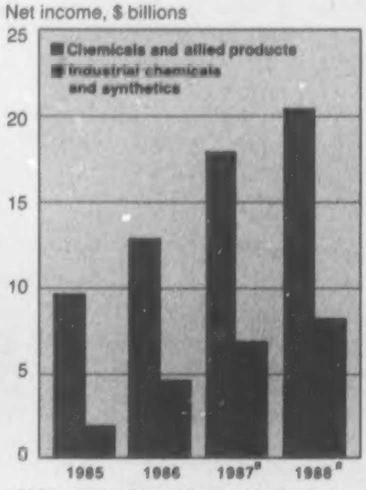
a C&EN estimates.
Source: Bureau of Labor Statistics

. . . and a steady rise in sales volume . . .



a Excludes sales of foreign subsidiaries. b C&EN estimates. **Source:** Bureau of the Census

. . . brings sharp growth for chemical producers' profits



a C&EN estimates. **Source:** Bureau of the Census pansion may slow during the latter half of 1988, the U.S. will enjoy an unprecedented sixth year of steady economic progress.

Probably the biggest uncertainty at present is the potential fallout from the stock market collapse. It is still too early to assess just how the $1 trillion or more in losses suffered by investors this past October and November will impact consumers' spending plans or businessmen's investment decisions. But consumers have been the linchpin in the economic expansion of the past few years, and if they indeed have been badly shaken by events on Wall Street, further growth in gross national product would likely be slowed—or even stopped.

If the economy does manage to eke out another year of slow growth, 1988 will be one more period of high production, rising sales, and strong profits for U.S. chemical firms. It is true, certainly, that two of their most important markets—housing and the automobile industry, both of which have been slumping this year—are likely to be less buoyant in 1988 as well. Housing starts this past October were at the lowest level since early 1983, and, for the year as a whole, starts probably will be down 10% from 1986. A decline of nearly the same size would not be surprising for next year, also. That, in turn, will undercut a big market for plastics, coatings, and fibers.

The automotive market, another vast outlet for these chemical products, also is facing cloudy prospects. For all of 1987, its sales probably will total about 10 million cars, down sharply from the 11.5 million sold last year. Consequently, car makers have been trimming back their output since midyear. Auto production is likely to total about 7.1 million units for the entire year, down 9 to 10% from 1986. And already, the three major U.S. car companies have trimmed their production schedules for 1988's first quarter to a level 13% below what they rolled off their assembly lines in this year's first three months. For all of 1988, output is likely to drop at least 5%.

Growth is likely to slow, also, for demand from other outlets, such as appliance and furniture makers and the textile industry. But even if chemical production does not rise appreciably above its present level, it will average about 4% higher next year than in 1987.

It's more likely, though, that production of chemicals, plastics, and synthetic fibers will rise 5 to 6%. Prices, too, probably will be 4 to 5% higher next year. That works out to at least a 10% increase in sales, to about $100 billion. And with costs under good control and plants operating mostly at optimum rates, profits are expected to continue to move up smartly. Although growth is not likely to be as extensive as this year's, a further rise of 15 to 20% seems a good bet.

On the other hand, if the economy should fall into recession before the end of 1988—an event that every business analyst is thinking about at present but most are still dismissing—chemical industry executives argue that most companies are now well positioned to ward off its effects better than at any time in the recent past.

The industry's leaner, fitter stature and robust balance sheets have made it more resistant to a slump in demand for its products. Earnings would be hurt, certainly, but they probably would hold up reasonably close to this year's levels. □

Continued moderate growth is likely for production of major chemicals and polymers

	1985	1986	1987	1988
INORGANIC CHEMICALS				
Thousands of tons unless otherwise indicated				
Ammonia	17,319	14,474	15,650	16,000
Chlorine gas	10,402	10,436	10,900	11,200
Hydrochloric acid	2,803	2,413	2,450	2,550
Nitric acid	7,645	6,734	6,800	7,100
Oxygen, billions of cu ft	357	347	365	380
Phosphoric acid	10,607	9,578	10,300	10,600
Sodium hydroxide	10,790	10,691	11,400	11,700
Sulfuric acid	39,890	35,759	38,500	40,000
ORGANIC CHEMICALS				
Millions of lb unless otherwise indicated				
Acetic acid	2,897	2,728	3,000	3,150
Acetone	1,788	1,910	2,050	2,100
Acrylonitrile	2,349	2,182	2,400	2,550
Benzene, millions of gal[a]	1,283	1,362	1,520	1,600
Butadiene	2,340	2,546	2,700	2,800
Cumene	2,627	3,745	4,200	4,500
Cyclohexane	1,657	2,070	2,250	2,400
Ethylene	29,847	32,859	33,800	35,500
Ethylene glycol	4,178	4,771	4,400	4,700
Formaldehyde	5,606	5,549	5,800	6,000
Methanol	5,003	7,205	7,450	7,800
Phenol	2,841	3,115	3,300	3,450
Phthalic anhydride	820	863	1,050	1,100
Propylene	14,887	16,522	18,200	19,600
Styrene	7,622	7,888	8,200	8,600
***o*-Xylene**	675	788	950	1,000
***p*-Xylene**	4,779	5,035	5,300	5,600
PLASTICS				
Millions of lb				
Polyethylene, high density	6,671	7,182	8,000	8,500
Polyethylene, low density	8,889	8,903	9,700	10,200
Polypropylene	5,139	5,812	6,650	7,100
Polystyrene	4,054	4,470	4,800	5,000
Polyvinyl chloride	6,772	7,256	7,950	8,250
SYNTHETIC FIBERS				
Millions of lb				
Acrylic and modacrylic	631	616	630	650
Nylon	2,343	2,514	2,750	2,850
Olefin and vinyon	1,249	1,393	1,480	1,550
Polyester	3,341	3,305	3,550	3,650

[a] Petroleum refiners only. **Sources:** Bureau of the Census, International Trade Commission, Society of the Plastics Industry's Committee on Resins Statistics, Textile Economics Bureau, C&EN estimates (for 1987 and 1988)

Foreign Trade

U.S. surplus in chemical trade broadens markedly as exports of chemical products surge

Thanks to the sagging dollar, U.S. chemicals are making bigger inroads in European and Asian markets

Earl V. Anderson, C&EN New York

The U.S. chemical industry is continuing to rebuild its once-dwindling chemical trade surplus, which had gradually shrunk from an impressive $12.1 billion surplus in 1980 to $7.2 billion by 1985. The industry pushed its surplus slightly higher to $7.8 billion last year, on the strength of a 5% increase in chemical exports.

This year, however, foreign trade of the U.S. chemical industry will increase substantially more. Thanks to a dollar that continues to grow weaker against major foreign currencies, chemical exports will jump a healthy 15% to about $26.2 billion. Meanwhile, the weaker dollar will help to limit chemical import growth to only 5%. If chemical imports do, in fact, weigh in at $15.7 billion this year, as expected, the U.S. chemical trade surplus will expand to $10.5 billion. And the chemical industry will have recouped two thirds of the decline in its trade surplus that it suffered in the early 1980s.

Given this year's strong export performance, the U.S. share of world chemical exports might be expected to increase. It won't. It will slip slightly to 14.4% from last year's 14.5% and the even higher 15 to 17% range in which it hovered during the early 1980s, when U.S. chemical export performance was much less vigorous than it is this year.

Why this statistical aberration? It certainly isn't because other countries are outperforming the U.S. when it comes to exporting chemicals. The answer, again, lies with the depreciating dollar.

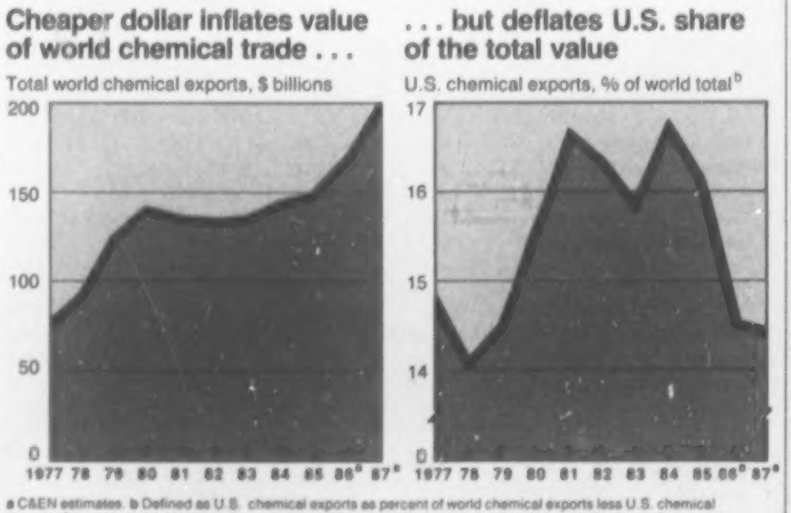
Measured in dollars, world chemical exports this year will fall just short of $200 billion. That's about a 15% advance, roughly the same percentage that world chemical exports (measured again in dollars) grew last year.

But realistically, the economies of the world's major industrialized nations just aren't strong enough to support that kind of growth in chemical exports. And the debt problems of many of the developing countries, particularly some of those in Latin America, make it impossible for them to boost their imports by such a large amount.

A more reasonable "guesstimate" of world chemical export growth this year is about 5% in real terms. The inflated 15% dollar-based figure results from the swiftly changing exchange rates of the dollar against other currencies.

Take, for example, the chemical exports of the European Community (EC). Most recent complete EC statistics (through June) show that EC chemical exports are actually running about 1% lower than they were last year. But EC reports its export figures in European currency units, or ECUs, which are weighted "basket" units based on the gross national product and trade of member countries.

In 1986, one U.S. dollar equaled 1.063 ECUs. This year, however, a dollar equals only 0.880 ECU, 17% lower than last year's conversion rate. Not surprisingly, EC chemical exports, measured in dollars, are up 19.5% over last year, even though they are down 1.2% in ECUs.



Cheaper dollar inflates value of world chemical trade . . .

Total world chemical exports, $ billions

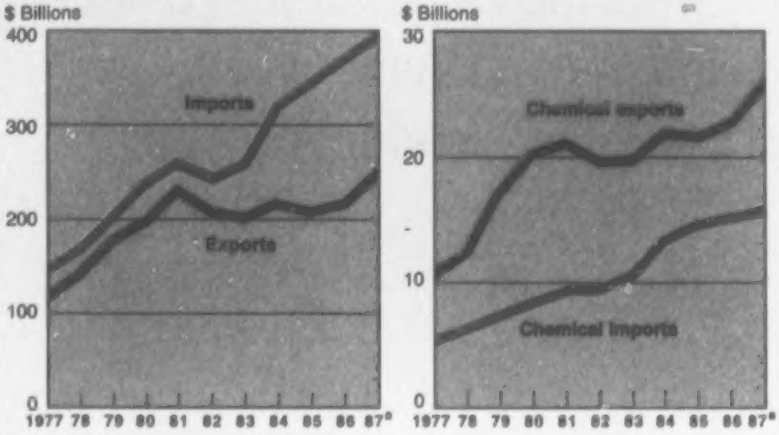
. . . but deflates U.S. share of the total value

U.S. chemical exports, % of world total[b]

a C&EN estimates. b Defined as U.S. chemical exports as percent of world chemical exports less U.S. chemical imports. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Community, Japan Ministry of International Trade & Industry

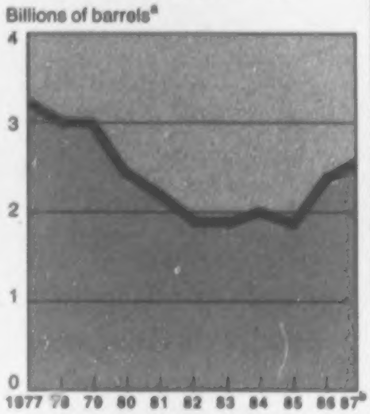
Deficit mounts higher for total U.S. foreign trade . . .

. . . but surplus in chemical trade shows improvement

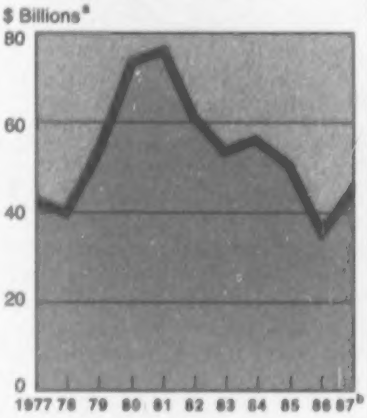


a C&EN estimates. Source: Bureau of the Census

U.S. is stepping up its petroleum imports . . .



. . . as higher prices escalate their total cost



a All petroleum products. b C&EN estimates. Source: Bureau of the Census

This is why U.S. chemical companies seem to be denied a higher share of world chemical exports, despite their strong export effort this year. The same story is repeated in Japan, where 1987 chemical exports will be 20% higher in terms of dollars, but less than 5% higher when valued in yen.

Because the weaker dollar makes imports from the U.S. less expensive in those countries whose currencies have appreciated most against the dollar, it is not surprising that most of the gains in U.S. chemical exports have come in the major industrialized nations. U.S. chemical exports to Western Europe, for instance, will be about 18% higher than they were last year. And the countries of Western Europe, as a bloc, make up the largest single U.S. chemical export market.

Although the Canadian dollar has not appreciated as much against the U.S. dollar as some European currencies have (especially the West German deutsche mark), U.S. chemical exports to Canada will score an impressive 30% advance this year. Chalk that up primarily to Canada's strong economy. U.S. chemical exports to Japan, however, are only 10% higher than last year, even though the yen has appreciated dramatically against the U.S. dollar.

Surge in U.S. chemical exports is sparked by organic chemicals and plastics

$ Millions	U.S. chemical exports				U.S. chemical imports			
	1987ᵃ	1986	1985	1984	1987ᵃ	1986	1985	1984
Organic chemicals	$ 7,650	$ 6,293	$ 6,012	$ 6,093	$ 5,385	$ 4,704	$ 4,576	$ 4,265
Plastics and resins	5,400	4,301	3,777	4,050	1,930	1,837	1,631	1,484
Medicinals and pharmaceuticals	3,275	3,090	2,708	2,628	1,380	1,240	1,084	931
Fertilizers, manufactured	2,095	1,935	2,160	1,815	770	865	967	1,142
Inorganic chemicals	2,045	1,771	1,967	2,184	1,995	1,894	1,984	2,064
Radioactive materials	915	1,302	1,311	1,421	800	1,382	1,417	1,394
Pesticides and disinfectants	785	664	614	707	410	580	399	308
Flavors, perfumes, cosmetics, and toiletries	575	488	478	498	740	679	577	521
Pigments, paints, and varnishes	420	333	322	335	425	348	266	232
Cleaning and polishing materials	365	302	292	308	205	214	172	118
Dyeing, tanning, and coloring materials	210	174	139	158	580	487	352	358
Explosives and pyrotechnics	80	81	100	146	125	111	103	84
Miscellaneous	2,385	2,032	1,878	1,992	955	660	1,005	797
TOTAL	$26,200	$22,766	$21,759	$22,336	$15,700	$15,001	$14,533	$13,697

a C&EN estimates. Source: Bureau of the Census

U.S. trade deficit rises despite higher exports of chemicals and other manufactured goods

$ Billions	U.S. exports 1987[a]	1986	1985	1984	U.S. imports 1987[a]	1986	1985	1984
Chemicals	$ 26.2	$ 22.8	$ 21.8	$ 22.3	$ 15.7	$ 15.0	$ 14.5	$ 13.7
Machinery and transportation equipment	104.7	95.3	94.3	90.0	173.7	161.6	137.3	119.2
Other manufactured goods	35.7	30.6	29.3	30.8	118.6	105.5	95.0	88.6
Food and live animals	18.7	17.3	19.3	24.5	20.8	20.8	18.6	18.0
Beverages and tobacco	3.4	2.9	3.0	2.9	4.0	3.9	3.7	3.7
Animal and vegetable oils and fats	1.0	1.0	1.4	1.9	0.4	0.5	0.7	0.7
Mineral fuels, lubricants, and related materials	7.6	8.1	10.0	9.3	43.6	37.3	53.9	61.0
Crude materials (inedible) other than fuels	19.5	17.3	16.9	20.2	11.2	10.4	10.4	11.1
All other products	19.9	11.0	11.0	10.1	12.0	14.9	11.1	9.8
TOTAL	$245.0[b]	$217.3[b]	$213.1[b]	$217.9[b]	$400.0	$370.0	$345.3	$325.7

a C&EN estimates. b Includes re-exported imports (not included in individual product categories). **Source:** Bureau of the Census

Where U.S. chemical exports, along with the exports of most other products, continue to suffer is in the debt-ridden developing nations. The most indebted nations, such as Brazil, are in Latin America, which is a very large and important outlet for U.S. chemicals.

In 1980, Latin America accounted for almost 24% of all U.S. chemical exports. But the debt problems of several of the region's largest and most economically advanced nations have put the brake on their ability to import. This year, for instance, U.S. chemical exports to Latin America will increase a miserly 1% over 1986. And the share of U.S. chemical exports that Latin America takes in will drop to only 15%.

On the other hand, U.S. chemical exports to developing nations in Asia are increasing rapidly. These nations, in fact, now rival Latin America as a big market for U.S. chemical exports.

The developing countries of Asia don't have the debt burden that Latin American countries do. And, led by the so-called newly industrialized countries, such as Taiwan, South Korea, Hong Kong, and Singapore, industrial development in this area has been swift.

As a result, this year U.S. chemical exports to the area likely will be up almost 20%. And its importance as a chemical market, compared with Latin America, has grown markedly. This year, the developing countries of Asia will import 15% of all U.S. chemical exports, about the same as Latin America's share. In 1980, those shares were 13% and 24%, respectively.

The betting is that developing Asia will continue to grow as a market for U.S. chemicals. But whether Latin America can regain its former stature is a big question. Most observers don't think it will happen any time soon.

It's a catch-22 situation in Latin America. The most heavily indebted countries there can't increase their borrowing to pay for additional imports. And to pay for their existing debt, they must run large trade surpluses. This, in turn, means throttling back on imports and increasing their own exports.

For them to increase their exports, however, implies that the industrialized countries, especially the U.S., must increase their imports from the developing country debtors. But the U.S., of course, has a troublesome trade deficit of its own.

Total U.S. exports this year probably will increase 13% to $245 billion. Imports, although held to only an 8% advance, nevertheless will reach a record $400 billion. This combination will push the U.S. trade deficit up slightly to $155 billion from last year's $152.7 billion, despite the effects of a much weaker dollar.

The U.S. will pay $45 billion for imports of oil and related products, almost $5 billion more than last year. Without this increase, the trade deficit would have been slightly lower than it was last year.

One expert sees a danger in lowering the trade deficit too rapidly. Albert M. Wojnilower, senior adviser and managing director of First Boston Corp., says that the deficit can be lowered by increasing exports and substituting domestic products for imports, by reducing domestic demand, or by protectionism. The first proposal, he says, could lead to inflation. The second is a euphemism for recession. And the third, protectionism, is hardly desirable. "I see no choice," says Wojnilower, "but to be content with glacial progress until the [newly industrialized countries] become vigorous buyers as well as sellers." ◻

Sales of U.S. chemicals to Europe, Asia, Canada rise sharply

$ Millions	1987[a]	1986
U.S. CHEMICAL EXPORTS		
Canada	$ 3,460	$ 2,668
Latin America	4,060	4,025
Western Europe	8,330	7,032
Eastern Europe	365	385
Japan	3,380	3,081
Australasia	840	689
Communist Asia	605	441
Middle East	365	345
Rest of Asia	4,035	3,377
Africa	500	447
Other	260	276
TOTAL	$26,200	$22,766
U.S. CHEMICAL IMPORTS		
Canada	$ 2,985	$ 2,752
Latin America	960	942
Western Europe	7,865	7,357
Eastern Europe	155	327
Japan	2,070	1,792
Australasia	235	221
Communist Asia	205	179
Middle East	265	238
Rest of Asia	645	623
Africa	80	326
Other	235	244
TOTAL	$15,700	$15,001

a C&EN estimates. **Source:** Bureau of the Census

Western Europe

Fertilizers and fibers are major weak spots in otherwise strong year for chemical producers

Despite slow growth in the overall economy for many chemical products, supplies now are tight

Dermot A. O'Sullivan, C&EN London

The European chemical industry is ending 1987 in excellent shape. Throughout 1987, demand for most of its products has been at record levels, many plants have operated above their original design capacities, and company profit margins, especially for petrochemicals, have been at their highest since 1979. The summer business lull that often shows up in slack results for the third quarter didn't materialize this year.

Market watchers are looking very carefully at the turn of events. Comments James W. Dawson, head of the planning and integration division at Shell International Chemical: "For several products, we have been seeing plant liftings (deliveries by producers) that are higher than can be explained by the growth in the European economies, by the general trading behavior, or by substitution effects. In other words, liftings seem a little overheated. This overheating might reflect the filling of the supply chain from the chemical producers to the ultimate user."

Certainly, many of Western Europe's macroeconomic indicators point to anything but a booming economic climate. Throughout the European Community (EC) as a whole, which comprises 12 of Western Europe's 17 countries, unemployment continues high, averaging 11.8% of the civilian labor force, little changed from last year.

On a more positive note, inflation in EC continued downward, with consumer prices up only 3.2% on average this year. Although the inflation rate may go up slightly to 3.4% next year, it will remain well below EC's 1980 average of 13.2%.

Gross domestic product, a key indicator of economic activity, on average this year is a mere 2.2% ahead of last year. The outlook for next year is that the rate of growth will be about the same. Spain registered the highest rise, a comparatively robust 4.1%, with Portugal not far behind at 3.7%. But half the EC countries are in the 1.2-to-2.5% range.

Contradicting such lackluster overall growth, however, demand at the consumer level remains high. A gradual lowering of interest rates, for example, has led in turn to a drop in mortgage rates, the cost of credit for buying cars, and the like, all of which provides a boost for chemical products.

According to a survey made by The Economist Intelligence Unit in London, output of cars by Europe's six main car manufacturing countries will reach nearly 11.9 million units this year, almost 4% more than in 1986. A dip is likely next year, but at an anticipated 11.6 million or so, the total still will exceed last year's level.

Automobiles are providing a growing market for plastics used for specialized engineering parts and to reduce weight. David Oxley at the London office of Chem Systems International believes that each vehicle may use, on average, 230 lb of polymers in 1990, about twice the amount that went into cars in 1980.

Growth in output of chemicals generally looks good. Industry groups in the Netherlands, Spain, Sweden, and the U.K. expect chemical output this year to increase 6% beyond 1986. Belgium, Finland, and Switzerland are the only countries of those polled for which growth has slowed, both this year and last.

Commodity petrochemicals have been in high demand throughout the year. Naphtha crackers have been running at near their design capacity load, with output of ethylene expected to reach 13.5 million metric tons or so in Western Europe, about 5% more than last year. Demand for propylene has been growing at an even faster rate, so much so, in fact, that the olefin is in tight supply.

In sharp contrast to a few years ago when crackers throughout Western Europe were being taken out of service because of a decline in demand for olefins, talk within the industry now centers on how best to bolster production. Indeed, Neste of Finland, in a link with Belgium's Petrofina, is considering a new cracker at Antwerp with an annual ethylene output capability of 500,000 metric tons. A decision will be made early next year.

The prospect of a new cracker coming onto the European scene isn't being viewed with universal approbation, however. A more prudent approach, some observers argue, is to continue debottlenecking existing units and to step up their output by upgrading the technology. This already is being done, and by BP Chemicals' estimates can provide Western Europe with an incremental gain of some 400,000 metric tons annually, about 3% of the current installed ethylene capacity. Moreover, there is potential in the system to allow this level of annual capacity "creep" to continue into the early 1990s.

Other petrochemicals, too, are in short supply, resulting in sharp price fluctuations during the year. Such is the case for styrene, as well as for plastics and synthetic elastomers made from it. Montedison, for one, is responding to the situation by installing a 440 million lb-a-year styrene plant in Italy. When it comes on stream in 1989, it will raise the company's annual capacity for the monomer, most of it used captively, to 1.1 billion lb.

Makers of commodity plastics—such as polyethylene, polypropylene, polystyrene, and polyvinyl chloride—are running their units flat out. The supply situation for conventional low-density polyethylene, in fact, is so critical in Europe that the plastic has been on allocation, a sharp change from a few years ago.

But it is polypropylene that is attracting the greatest amount of attention. The list of companies with plans for new European plants reads like a who's who of the industry, as the premise is that demand will continue to rise well into the next decade. Jacobus Franke, polypropylene marketing manager at DSM in the Netherlands, one of the companies with expansion plans, predicts that demand in Western Europe will increase from last year's 5.13 billion lb to 6.4 billion lb in 1990, and 7 billion lb in 1993. If his projection is accurate, and all the plans so far unveiled materialize, West European supply in 1993 might exceed demand by 1 billion lb.

Stuart H. Wamsley, who recently joined Morgan Stanley International, in London, as chemicals analyst, voices alarm at the new round of capacity increases taking shape in Europe. Recalling the severe rationalization and retrenchment that the industry went through in recent years, he contends that "many managers have yet to adjust to the fact that a degree of supply tightness will generate profits, while oversupply is more likely to lead to losses. The most cost-effective and profitable way of coping with the present tightness of supply without jeopardizing the future is for producers to continue maximizing the efficiency of their plants and processes. Such a course will provide more profit more quickly."

Shell's Dawson points out that if investment decisions are made simply by extrapolating from the present situation and there is a downturn in the economy when the plants are coming on stream, "then the industry would be faced with another of its years of concern. History has shown that you don't get it right in petrochemicals if you don't get the fundamentals right. We are being careful how we make our investment decisions, basing them on a variety of factors. Obviously, if the economy goes along reasonably steadily, then for certain products extra investment will be justified. But I advocate that we exercise much vision with vigilance."

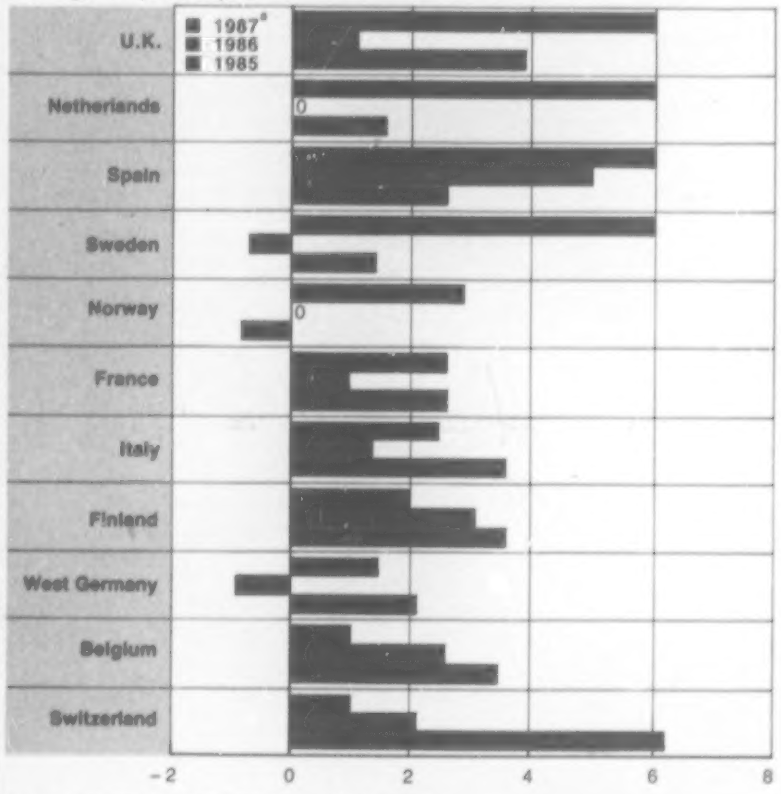
Fertilizers remain a depressed segment of the industry. And although the global market for nitrogen fertilizers may be heading for a slight upturn, thereby narrowing the gap between supply and demand, agriculture throughout Europe remains plagued by high stocks and overproduction of farm products. The consensus overall is that there is little prospect for growth in fertilizer usage.

European fertilizer producers, moreover, are having to cope with urea arriving in sizable quantities, much of it at dumped prices, from many sources, the U.S. included. CMC-Engrais, the association representing Western Europe's fertilizer makers, claims that these imports during the 1986–87 fertilizer year amounted to 911 million lb, four times greater than three years before. The share of the EC urea market that these imports captured increased from less than 4% to 12% in the same time period, CMC-Engrais maintains.

Consolidation moves likely will improve the economics of fertilizer operations, however. For instance, Kemira, an established fertilizer

Chemical output growth stronger in many European nations

% change from previous year

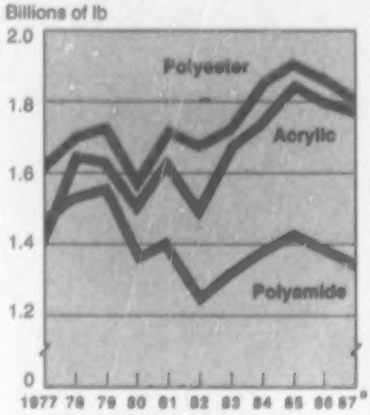


a Estimated. **Source:** National chemical federations for each country company in Finland, has acquired the operations of Gechem, the chemicals arm of Belgium's Société Générale de Belgique. And Norsk Hydro has taken over full ownership of France's Cie. Française de l'Azote, giving it a one-third stake in French fertilizers.

Synthetic fibers haven't been doing particularly well in Europe, either. Production of acrylic, polyamide, and polyester fibers will be down this year, following a decline last year as well. Output of acrylics is expected to drop to 1.77 billion lb, more than 4% off the 1985 level. Production of polyamide, at 1.35 billion lb, and of polyester, at 1.80 billion, each will be 6% less than in 1985.

According to a recent study by Stanley Davies of The Economist Intelligence Unit, restructuring of the fibers industry probably is not yet complete. There may be some company mergers or product line exchanges, he believes, as producers try to increase their share of specific market sectors, so as to reduce overhead costs in what is virtually a static market.

Production of fibers sputters in West Europe



a Estimates. Source: CIRFS (International Rayon & Synthetic Fibers Committee)

The U.S. dollar has undergone a steady decline in value against European currencies since early in 1985. By September, the exchange rate was down more than 45% from its March 1985 peak against the Dutch guilder and West German deutsche mark. The fall was 43% against the Belgian franc, 40% against the French franc, 37% against the Italian lira, and 33% against the U.K. pound. The dollar's weakness has continued throughout October and November.

The decline is viewed with some concern by European bankers and economists who have been anxiously looking to Washington to see what steps are being taken to halt the decline. Their present stance is a reversal from a few years back, when criticism was leveled at the dollar's growing strength.

Currency parity is a complex issue. A weaker dollar has both negative and positive ramifications for European chemical companies. One negative effect is that dollar sales

How to close the critical gap between measurement hardware

© 1987 Lotus Development Corp. Lotus, 1-2-3 and Symphony are registered trademarks and Lotus Measure is a trademark
DOS 2.0 or above. 1-2-3 Rel. 2.0 or above, Symphony Rel. 1.1 or above. Data collection hardware not included. Demo

and earnings translate into lower figures in the currencies of the countries where the companies are headquartered. Conversely, of course, the sales and profits of the European arms of U.S. firms look particularly good right now when viewed in dollar terms.

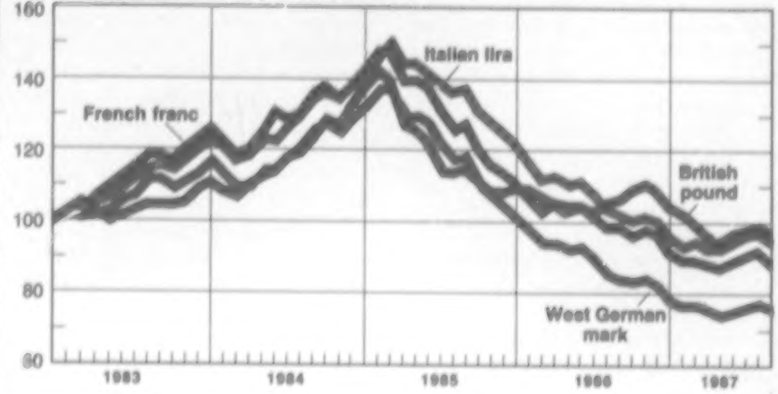
Another negative, so far as the Europeans are concerned, is that they risk losing their competitive edge against U.S. exports. So far, this has most affected goods sold in dollar trading zones.

London-based ICI comments that as yet, "U.S. producers have not moved into European markets in a significant way. With a prolonged period of dollar weakness, or a large downturn in the U.S. market, this could change, however."

European companies gain from a weaker dollar, on the other hand, when they purchase oil and naphtha, which are priced in dollars. So petrochemical feedstocks, in local currencies, become less expensive.

Dollar plummets to lowest level in more than five years

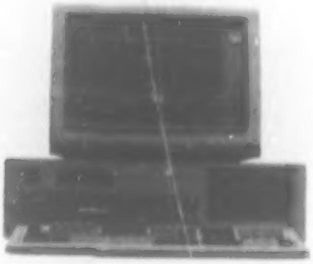
Relative value of U.S. dollar versus four Western European currencies, January 1983 = 100



Source: International Monetary Fund

As David Glass of Chem Systems International points out, European companies are disadvantaged when their fixed costs are calculated in U.S. dollars. He cites the case of a hypothetical naphtha cracker in West Germany that incurred fixed costs of, say, $35 per ton of ethylene when the dollar was at its high of 3.26 deutsche marks in 1985. Today, even assuming that fixed costs have come down since then because

and your spreadsheet.



Lotus® Measure™ seamlessly connects your measurement hardware and 1-2-3® or Symphony® spreadsheets in real time, for immediate display, analysis, and storage of instrument data. No more retyping data or wading through printouts. No more wasted time.

Lotus Measure can set up and collect data from your RS-232-C and IEEE-488 compatible instruments, or take data using an A/D board.

For a brochure and free demo package, call **1-800-345-1043** and request demo kit HC-1674.

Lotus Measure

Lotus Measure

of Lotus Development Corp. System requirements: IBM® PC, XT™ AT® HP® Vectra® PC or COMPAQ® Portable; 512K RAM
disk requires DOS 2.0 or above; IBM or compatible personal computer and Hercules® CGA, or EGA compatible display

of improved operating rates, the dollar equivalent is about $64 per ton because of the weaker dollar, an 85% increase. The increase in fixed costs is especially significant when European producers are competing against their U.S. counterparts in export markets priced in dollars. Moreover, it confers an advantage to U.S. imports into Europe itself.

Another outcome of the lower dollar is that it costs European companies less, in terms of their local currencies, to make U.S. acquisitions. European managers argue that such acquisitions are decided on when they are seen to fit into longer term corporate strategies, independent of the exchange rate at the time. But they acknowledge that their purchases this year and last were less expensive than they might otherwise have been.

Such purchases have continued apace. Just last month, West Germany's Bayer further strengthened its U.S. position by buying Denka Chemical of Houston. Its chemicals are used to make agrochemicals, lube oil additives, polyester resins, and the like, areas in which Mobay, Bayer's U.S. subsidiary, already is active. In addition, Scientific Design, part of Denka, makes catalysts and provides chemical engineering and process licensing services.

This year also saw the incorporation of Celanese into Hoechst, an acquisition that was negotiated in the closing weeks of 1986. The move greatly enhances the U.S. presence of the West German company, providing it with a range of fibers and plastics, together with organic chemical intermediates.

Courtaulds, a leading chemicals and textiles company based in London, is paying $140 million for Porter Paint of Louisville, Ky., a specialty maker of architectural coatings, enamels used in the graphic arts, and coatings for concrete and steel. Its activities will mesh with those of Courtaulds' International Paint subsidiary in the U.S.

ICI, meanwhile, has further extended its presence in the U.S. by acquiring Stauffer Chemical from Unilever, the Anglo-Dutch chemicals and foods giant. Within weeks of the midyear purchase, ICI hived off Stauffer's specialty chemicals businesses to Akzo and two months later followed this with sale of the basic inorganic chemicals part of the organization to France's Rhône-Poulenc. Three remaining small segments of the original Stauffer concern also will be sold, leaving ICI with Stauffer's extensive pesticide operations, which attracted ICI to Stauffer in the first place.

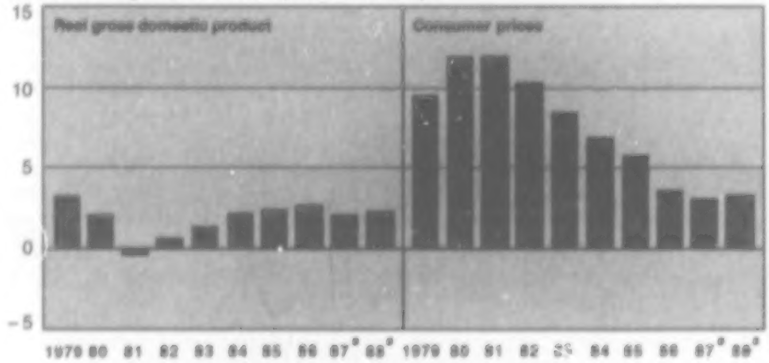
BP Chemicals also has gained a stronger U.S. position on the chemicals scene as the result of this year's purchase by British Petroleum, its parent company, of the 45% of Standard Oil it hadn't already owned. The Cleveland-based oil company's chemicals arm now is the Sohio division of BP Chemicals. In a separate move, BP Advanced Materials, another branch of the U.K. oil firm, bought Hitco from Owens-Corning Fiberglas.

Compared with such purchases by Europeans, entailing commitment of very large sums of money and resulting in their ownership of large segments of the U.S. chemical industry, steps being taken by U.S. chemical companies in Europe may appear comparatively modest. But this doesn't mean that their intention to maintain a presence there has lessened. In general, though, the expansions that are in progress center on selective areas in which the U.S. companies see themselves with a technical edge over the competition and where high growth is foreseen.

Arco Chemical, for instance, is set to become a leading European supplier of fuel oxygenates—*tert*-butyl alcohol (TBA) and methyl *tert*-butyl ether (MTBE)—with an eye to rising demand as lead additives are legislated out of gasoline. An 836 million lb-a-year TBA unit nearing completion at Fos in the south of France will raise the company's European annual capacity to 2.05 billion lb. And Arco will be the big-

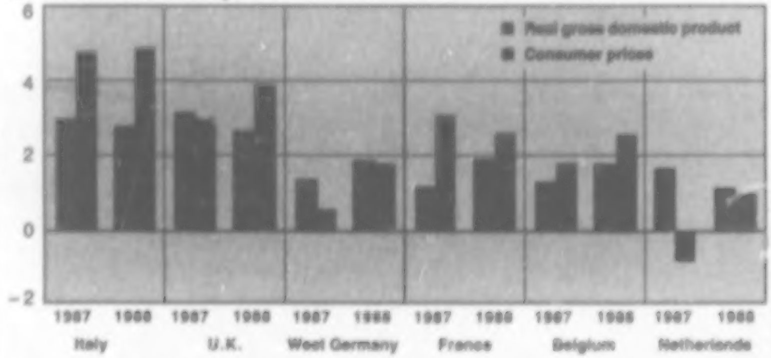
Inflation remains low but economic growth is slim . . .

% annual change for overall European Community



. . . with expansion strongest in the U.K. and Italy

Estimated % annual change



a Estimates. Source: Commission of the European Community

Vehicle output may slacken

	Millions of cars and trucks			% change from previous year	
	1986	1987[a]	1988[a]	1987	1988
West Germany	4.60	4.61	4.35	0%	−6%
France	3.20	3.33	3.28	4	−2
Italy	1.83	1.89	1.89	3	0
Spain	1.53	1.60	1.65	4	3
U.K.	1.25	1.41	1.38	13	−2
Sweden	0.49	0.49	0.50	0	2
TOTAL	12.89	13.33	13.06	3%	−2%

a Estimated. Source: The Economist Intelligence Unit

gest producer of MTBE when units going up at Fos and Rotterdam come on stream, possibly next year.

Arco Chemical also strengthened its position in propylene oxide-based polyols this year by taking ownership of a Belgian 154 million lb-a-year operation from France's Atochem. And, partnered with EniChem, it is building a facility in Italy for making 24 million lb annually of Dylark, Arco Chemical's proprietary line of styrene-maleic anhydride engineering plastics.

Dow Chemical, which this year withdrew from North Sea oil and gas exploration and drilling, also has linked with EniChem, the petrochemicals arm of Ente Nazionale Idrocarburi, Italy's state-owned energy and hydrocarbons concern. Together, they will make special grades of advanced epoxy resins at EniChem's existing facilities at Pisticci in southern Italy.

Du Pont also has gone into business with EniChem by taking a 50% equity stake in Sclavo, a medical diagnostics and pharmaceuticals company based in Siena, Italy. Products include blood derivatives, vaccines, and industrial enzymes. In another venture with EniChem, Du Pont will provide its Aldyl polyethylene piping system for the natural gas industry, supplying product from its plant in England.

Elsewhere, Du Pont has a number of new projects under way. Ground breaking has taken place for a plant at Izmit, Turkey, where industrial nylon 66 yarn for tire reinforcement and other applications will be made in conjunction with the Turkish company, Haci Omer Sabanci. Adiponitrile to be used will come from Butachimie in France, jointly owned by Du Pont and Rhône-Poulenc. In Northern Ireland, Du Pont is readying a plant that will spin its Kevlar aramid fiber at an initial rate of 15 million lb annually. In Luxembourg, Tyvek spun-bonded polyolefin fabric soon will be made in a 44 million lb-a-year facility. And responding to a shortage of polyvinyl butyral film used as an interlayer in shatterproof glass, Du Pont will produce the material at Uentrop, West Germany, its first such unit outside the U.S. Growth in demand for the product also has prompted Monsanto to invest in additional capacity at its Belgian facility.

Recent unveiling of plans by West European companies to establish joint ventures in the U.S.S.R. could be the forerunner of other such moves in 1988 and beyond. Italy's Montedison and Occidental Petroleum, together with Marubeni of Japan, are linking with the Soviet Union's oil ministry in a major petrochemicals undertaking that could involve investment of up to $6 billion. Slated for the Ural region, the complex will draw on oil and gas produced in the area, and the non-Soviet partners will be allowed to export their share of the output.

Another project involves production of sulfur dyes, used mainly to color cellulosic fibers, by Tauria, a new company owned 49% by Switzerland's Sandoz and 51% by Soyuzanilprom, the U.S.S.R. organization responsible for dyes. A plant will be sited at Armyansk on the Black Sea east of Odessa. Sandoz will have exclusive rights to sell the dyes outside East Bloc countries.

These and other ventures that may emerge mark a departure from the commercial activities that took place with the U.S.S.R. in the past. The change reflects the drive by Soviet leader Mikhail Gorbachev to expand his country's economy and extend trade relations with the West. Some observers believe that as many as 200 or so joint-partnership projects are being discussed, not all of them, of course, focused on chemicals.

Europe's leading chemical companies, meanwhile, are directing increased development funding into commercial areas that until now haven't usually been associated with the more traditional thrust of the industry. Hoechst, for example, is moving further into advanced ceramics and the fabrication of engineering components made from them. ICI is adding to its team designing complete electronic systems, an outgrowth of a decision a few years ago to develop chemicals needed by the electronics industry.

Many European companies, too, are engaged in one aspect or another of genetic engineering. One of the most dramatic of these, with enormous commercial and social potential, is the search for novel crop varieties through the genetic manipulation of seeds.

Italy's EniChem is seeking crops that will have the inherent ability to resist fungal attack and to absorb nutrients with greater efficiency. And it has linked with the Max-Planck Institute of Crop Cultivation and Production Physiology in Cologne, West Germany, on work that could lead to plants that are immune to viruses.

ICI continues its aggressive entry into the seeds business with its recent purchase of MMG, a U.K. cereal seed-breeding company. This follows its June acquisition of the Belgian European Seeds Co. and, in the past couple of years, of Garst Seed in Iowa and Sinclair McGill in the U.K. And Shell International Chemical, already well entrenched in the seed business, this year decided to inject $20 million during the coming five years largely into seeds-related areas of research and agricultural biotechnology. This figure is above the existing rate of investment of about $20 million a year that Shell spends on plant genetics in the U.K. and elsewhere.

Such projects essentially are long term. "They need a great deal of faith," remarks Shell's Dawson. "But we certainly have that." □

Reprints of this C&EN special report will be available in black and white at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.

Strong domestic economy buoys chemical demand and profits

Chemical producers are focusing more on home markets as strong yen dims prospects for exports

Earl V. Anderson, C&EN New York

One Japanese chemical company has changed its name and another is planning to. In October, Toyo Soda Mfg. Co. became Tosoh. Now, Mitsubishi Chemical Industries wants to change its name to Mitsubishi Kasei.

Whatever the companies' reasons, these name changes are indicative of the chemical scene in Japan, where change is the name of the game. Companies strong in basic or commodity chemicals are pushing into every conceivable nook and cranny of specialty chemicals and other high-tech product areas.

Over the past few years, thousands of tons of basic chemical plant capacity has been scrapped in a major petrochemical industry restructuring effort. Now, however, demand for many basic petrochemicals is pushing output to capacity limits. Japanese chemical companies consequently are switching their thinking from scrapping to building.

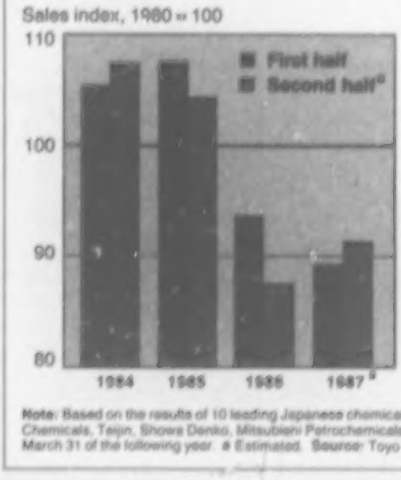
A year ago, Japanese chemical executives, along with those of virtually every other industry, worried about what would happen to their profits as the yen strengthened from 200 to the U.S. dollar in December 1985 to 150 in December 1986. Now, the yen has strengthened further to below 133 to the dollar. Yet profits, rather than tumbling, have soared.

Why? No doubt the emphasis on high value-added products has helped some Japanese chemical companies. But it's still too early in the transition to high tech for that to make a significant impact.

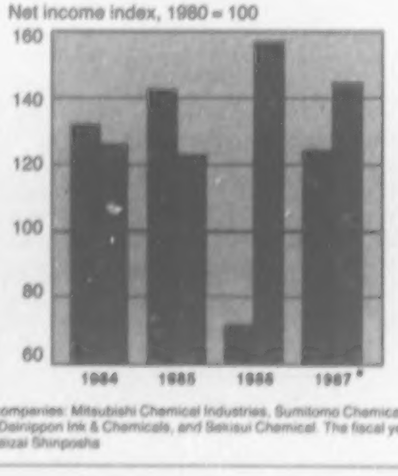
The bigger reason is that Japan has made the conversion from export-led economic growth to growth based on domestic demand much faster—and better—than expected. Certainly the Japanese economy has recovered from the beating that it took from the soaring yen in 1985 and 1986.

The Japanese government had pegged economic growth for fiscal year 1987, which ends in March 1988, at 3.5%. However, that growth may be somewhat lower—about 2.9% or 3%—with the yen at its present level of about 135 to the dollar. But whatever the economic growth rate, chemical company profits have been the beneficiary of this economic recovery. The domestically oriented economic spurt, buttressed by increases in housing starts, stronger domestic production, and higher consumer spending, has pushed up demand for many chem-

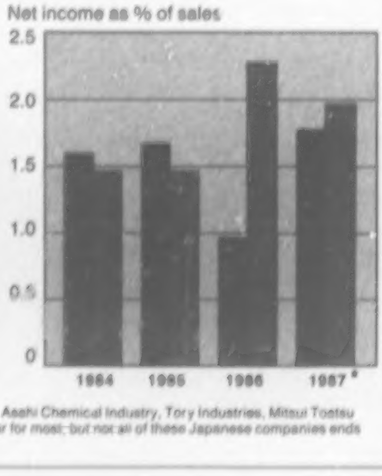
Sales stagnate for Japanese petrochemical firms . . .



. . . but net income will rise for the year as a whole . . .



. . . so that profit margins are holding firm



Note: Based on the results of 10 leading Japanese chemical companies: Mitsubishi Chemical Industries, Sumitomo Chemical, Asahi Chemical Industry, Tory Industries, Mitsui Toatsu Chemicals, Teijin, Showa Denko, Mitsubishi Petrochemicals, Dainippon Ink & Chemicals, and Sekisui Chemical. The fiscal year for most, but not all of these Japanese companies ends March 31 of the following year. * Estimated. Source: Toyo Keizai Shinposha ical products, including petrochemicals.

At midyear, production for all chemicals was a healthy 9.5% higher than it was a year earlier. Petrochemical production was up 10% and plastics output was running 11% higher. However, synthetic fibers, synthetic rubber, and fertilizer were among the chemical products that did not benefit from the economic upturn. For all of them, production was down.

Despite these weak spots, demand for chemicals has improved markedly during the past year. In addition, price increases, lower interest payments, and lower raw material costs are boosting profits for most Japanese chemical companies.

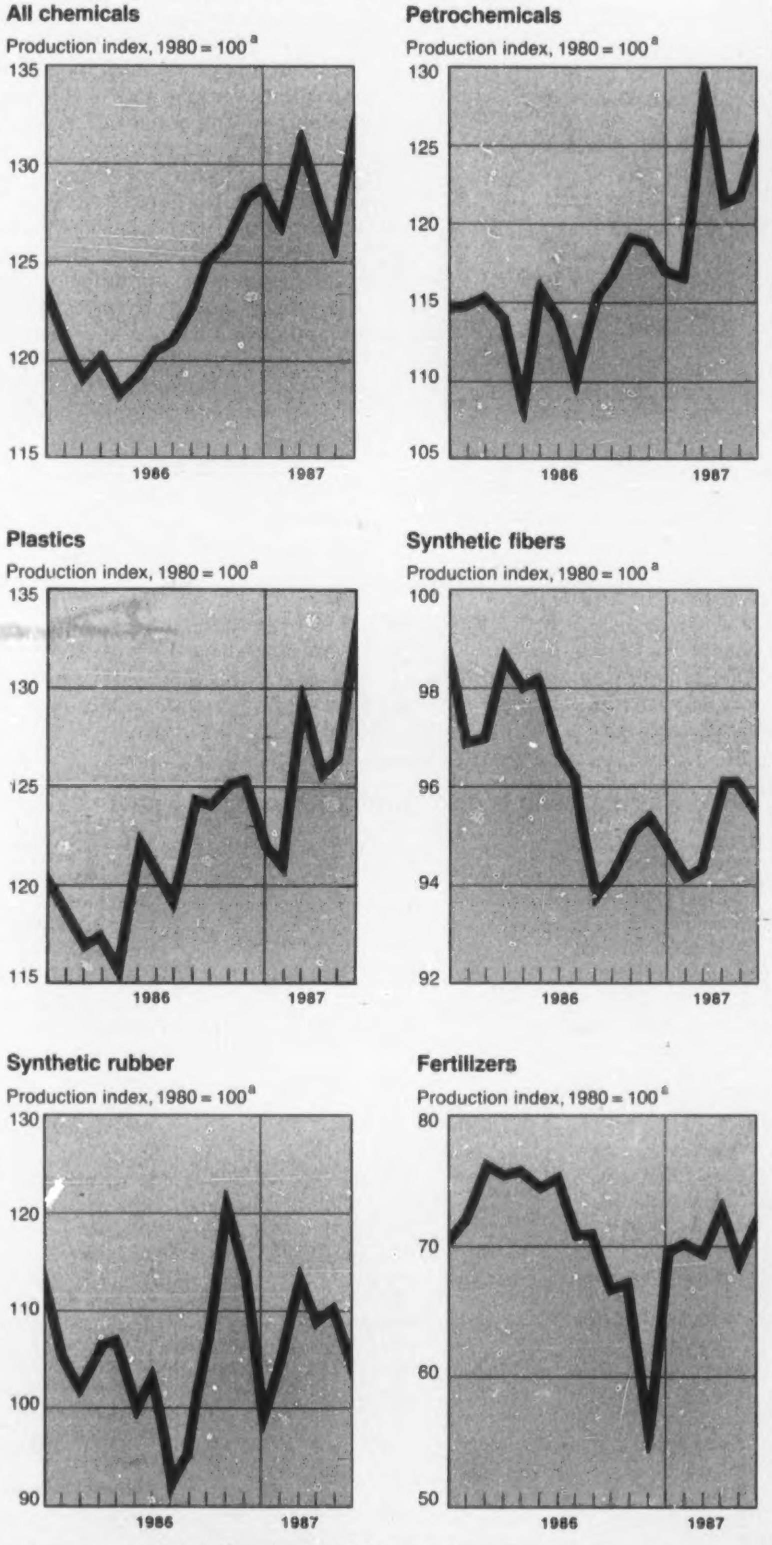
Showa Denko, for instance, expects profits for its fiscal year ending this month to increase almost 75% over last year. Mitsubishi Petrochemical foresees profits that will more than double those of a year ago. The profit picture was especially rosy in the first half of the fiscal year. A profit index of 10 leading Japanese chemical companies indicates that net income shot up 73% in the first half of fiscal 1987, compared with the first half of fiscal 1986.

The questions now uppermost in the minds of most Japanese chemical company executives are: What will happen to the yen-dollar exchange rate? How will it affect the domestic economy next year? And what will happen to chemical company profits?

The first question is difficult to answer. But it's not difficult to extrapolate what will happen to chemical industry profits if the yen does appreciate further against the dollar. According to a spokesman for Mitsubishi Chemical Industries, an even stronger yen will make life tougher for its customers. This, in turn, will hurt the company's business—and profits.

According to the respected Nomura Research Institute, at a yen-to-dollar rate of 140, the average profit of 100 major Japanese companies would go up 27% in fiscal 1988, ending March 1989. However, if the yen appreciates to 130, the fiscal 1988 profit advance will be limited to 17%.

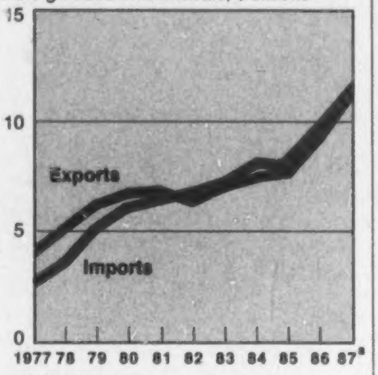
Output of chemicals generally higher this year



a Seasonally adjusted. **Source:** Ministry of International Trade & Industry

Chemical imports continue to hold slight edge on exports

Foreign trade in chemicals, $ billions



a C&EN estimates.
Source: Ministry of International Trade & Industry

But Japanese companies, including chemical companies, have become adept at coping with a stronger yen. Many have developed strategies for remaining profitable, even with a stronger yen.

The imponderables about the future yen exchange rate hasn't held back chemical industry capital investment. A survey by the Economic Planning Agency conducted in March indicated that capital spending plans by all industry in fiscal 1987 called for only a 1.4% increase over the previous year. A more recent survey, in September, puts the increase at 7%. Capital spending in the chemical industry, however, will advance 17%, the agency adds.

Meanwhile, the Japan Chemical Industry Association says that most of its members expect that business will remain good, at least through the end of this fiscal year. For many chemicals, demand continues strong and supplies are tight. Vinyl chloride and ethylene dichloride are two examples.

Ethylene, the bellwether of the petrochemical industry, is enjoying a banner year. Output is expected to top 4.6 million metric tons, second only to the record 4.78 million metric tons produced in 1979.

Most Japanese ethylene producers are operating their plants at full capacity. The same is true of other products. Inventories of ethylene derivatives are declining.

If this good fortune is to continue, the impetus for growth will have to come from domestic markets more so than from exports. Japanese chemical exports are likely to increase 20% this year to $11.4 billion. But measured in yen, the increase is less than 5%.

Because of the strong yen, the prospects for dramatic increases in chemical exports are slim. On the other hand, that same strong yen could lure in more chemical imports.

Japanese chemical imports this year probably will hit $11.5 billion in 1987. Although that's an 18% increase measured in dollars, it's only a 2.5% increase when measured in yen.

But chemical imports may climb faster in the future. Japanese chemical leaders expect increasing chemical imports from the so-called "newly industrialized countries" of Asia, particularly South Korea and Taiwan. Indeed, as Japanese chemical companies participate more in joint-venture production in these countries, chemical shipments back to the homeland are bound to rise. □

Production growth is strongest among organic chemicals and plastics

Thousands of metric tons unless otherwise indicated	1986	Six months 1987	Six months 1985	% change
INORGANIC CHEMICALS				
Ammonia	1794	871	901	−3
Ammonium chloride	364	185	190	−3
Ammonium sulfate	1784	897	893	1
Calcium carbide	399	200	224	−11
Calcium superphosphate	514	269	278	−3
Carbon black	616	309	311	−1
Chlorine, liquid	881	452	458	−1
Hydrochloric acid	549	269	269	0
Nitrogen[a]	6293	3162	3137	1
Oxygen[a]	6786	3322	3429	−3
Sodium carbonate	1022	557	514	8
Sodium hydroxide	3077	1575	1524	3
Sodium silicate	603	313	289	8
Sulfuric acid	6561	3259	3383	4
Titanium dioxide	223	120	115	4
ORGANIC CHEMICALS				
Acetaldehyde	254	140	123	14
Acetic acid	300	165	135	22
Acetone	228	132	112	18
Acrylonitrile	546	271	266	2
Benzene[b]	2071	1146	1014	13
Butadiene	656	339	324	5
Butanol	248	120	113	6
Caprolactam	448	233	223	5
Cyclohexane	515	276	262	5
Dioctyl phthalate	257	128	124	3
Ethylene	4291	2247	2073	8
Ethylene dichloride	1908	1021	926	10
Ethylene glycol	339	167	186	−10
Ethylene oxide	489	251	259	−3
Methanol	221	85	125	−32
Octanol	235	110	102	8
Phenol	260	162	126	29
Phthalic anhydride[b]	163	82	74	11
Propylene	3167	1650	1515	9
Propylene glycol	223	114	106	8
Styrene	1417	758	674	13
Terephthalic acid	1035	491	473	4
Toluene	805	428	404	6
Toluene diisocyanate	86	40	38	5
Urea	778	369	429	−14
Xylene	1570	856	756	13
PLASTICS				
Phenolic resins	313	159	155	3
Polyethylene	2066	1059	987	7
Polypropylene	1333	712	660	8
Polystyrene	1598	827	778	6
Polyvinyl chloride	1540	875	744	18
SYNTHETIC RUBBER	1150	586	576	2

a Millions of cubic meters. b Petroleum-based product only. **Source:** Ministry of International Trade & Industry

Canada

Profits make a strong recovery for the chemical industry

Exports are outpacing domestic demand for chemical products, but fertilizers remain depressed

Earl V. Anderson, C&EN New York

Canadian chemical firms came roaring out of the third quarter of 1987 with strongly improved profits. And, although Black Monday—Oct. 19—raised havoc with their stock prices, as it did with those of their U.S. competitors, at least some Canadian chemical company leaders don't expect their sales or earnings to slow down during the fourth quarter.

J. Edward Newall, chairman and president of Du Pont Canada, says that the outlook for the fourth quarter "remains excellent." And Paul H. Williams, executive vice president of Celanese Canada, expects that improved profits in many product lines, including polyester staple fiber, chemicals, and industrial products, will give his company an excellent year.

Indeed, most Canadian chemical companies would be happy with their 1987 results any year. But the chances that 1988 will be a repeat of 1987 as far as profits are concerned are very slim.

Like it or not, Canada's economic health depends heavily upon the economy in the U.S. And although few U.S. economists think that the October stock market debacle will trigger an outright recession, most now are scaling back their growth estimates for 1988.

That's true in Canada as well. There, real gross domestic product will grow about 3.5% this year, and the consensus of earlier economic forecasts for 1988 had put GDP growth in 1988 at about 2.5 to 3.0%. Now, however, forecasters have revised their growth estimates downward to 2.0 to 2.5%. And very few are willing to deny that the possibility of an economic downturn at least exists.

Either way, profits of Canadian chemical companies probably won't be up so strongly in 1988 as they will be this year. The combined profits of the four publicly traded companies regularly tracked by C&EN (C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada) soared a hefty 130% in 1987's third quarter. For the first nine months, the combined profits of these companies were up more than 50%. This was despite a sales rise of only 10% in the third quarter and a mere 2% for the first nine months.

A large portion of those profits come from a much-improved export market. Du Pont Canada, for instance, says that this year's export demand for industrial yarns, polyethylene, and specialty polymers has been particularly strong. And for Celanese Canada, chemical sales to Europe have been exceptionally brisk. In fact, the company says it is "sold out" in some products.

The export market is growing more rapidly than the domestic market for the Canadian chemical industry. Statistics through August (the latest available) indicate that shipments of Canadian chemicals and chemical products are 3 to 4% higher than they were last year. That's better than the shipments for all manufacturing industries, which are up only 2.3%. But this year, Canadian chemical exports probably will increase a solid 15% to $4.5 billion (in Canadian dollars, the increase is a less dramatic but still sizable 9%). Higher prices, as well

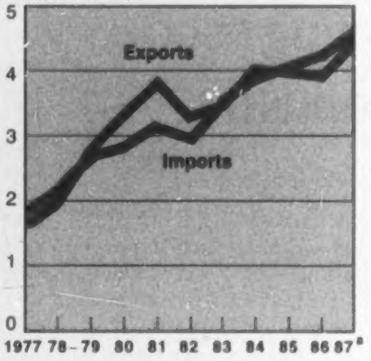
Petrochemical output surges as fertilizer chemicals slump

	Production					% change
Thousands of metric tons	1987[a]	1986	1985	1984	1983	1986–87
Ammonia	3060	3540	3620	3493	2888	−14%
Ammonium nitrate	765	948	1054	969	934	−19
Ammonium phosphate	925	1149	1301	1383	1259	−19
Benzene	755	635	688	557	580	19
Chlorine	1615	1536	1424	1424	1385	5
Ethylene	2170	1909	1744	1464	1196	14
Hydrochloric acid, 100%	153	153	158	161	170	0
Phosphoric acid, 100%	525	547	627	691	656	−4
Polyethylene, high density	270	242	229	227	211	12
Polyethylene, low density	1020	887	733	529	412	15
Propylene	650	628	648	665	715	4
Sodium chlorate	430	373	336	313	294	15
Sodium hydroxide	1770	1696	1589	1575	1528	4
Sulfuric acid	3425	3536	3890	4053	3686	−3
Urea	2000	2330	2033	2110	1445	−14

a C&EN estimates. Source: Statistics Canada

Deficit narrows for foreign trade in chemicals

$ Billions (U.S.)



a C&EN estimates. Source: Statistics Canada

as higher volume, are helping to swell the total.

As usual, synthetic resins and elastomers are leading the export parade. Canadian plastics exports probably will be up 25 to 30% this year. Polyethylene has been a particularly strong export performer.

The one major blight on an otherwise stellar export performance is fertilizers. Weak demand and weak prices, particularly in the all-important U.S. market, continue to haunt Canadian fertilizer exports. Fertilizer sales in foreign markets are down from 15 to 40%, depending upon the particular product. Ammonium nitrate exports are particularly depressed.

This export record is reflected in Canada's chemical production picture. Output of plastics and their precursors, such as ethylene, is up sharply. Production of fertilizer materials, on the other hand, is down substantially.

By year's end, low-density polyethylene production in Canada likely will top 1 million metric tons, about 15% more than last year. Output of high-density polyethylene also will be up about 12% to 270,000 metric tons.

Statistics for polystyrene and polyvinyl chloride aren't reported in Canada, but they probably are having banner years as well. These plastics, along with the polyethylenes, are creating a strong demand for ethylene in Canada, a demand that Canadian producers are hard-pressed to meet.

Ethylene output is likely to come close to 2.2 million metric tons in 1987, a 14% increase over last year. Canadian ethylene producers say that their plants are running full out. Little wonder, then, that Alberta Gas Ethylene has reactivated plans to build its third ethylene plant in Alberta, which will have an annual capacity of 680,000 metric tons. Along with some debottlenecking in two existing units, the new plant will bring the company's total ethylene capacity up to 2.04 million metric tons per year when it comes on stream in late 1991.

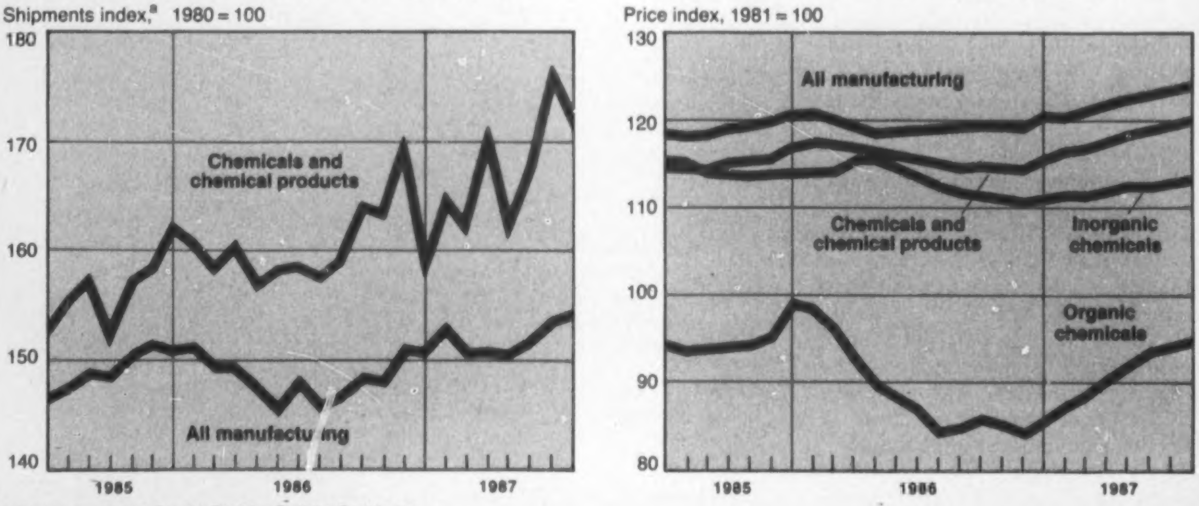
Meanwhile, fertilizer output is hard hit by poor export markets. Canadian ammonia production is estimated to be down 14% this year. Ammonium nitrate and phosphate output will tumble nearly 20%, and urea will suffer a 14% decline. Fertilizer producers say that nothing short of a drastic turnaround in exports will pull them out of their prolonged slump.

If the uncertainty or lack of consumer confidence triggered by Black Monday does slow down economic growth next year, Canadian fertilizer companies will have to wait even longer for their recovery. Most of Canada's chemical companies won't be as hard-pressed as fertilizer producers by slower economic growth in 1988. But there's little chance that they will manage to duplicate this year's strong profit growth again next year.

A slower-growing economy, or even an economic downturn, won't batter Canadian chemical companies the way they were in the 1981–82 recession. Since then, the major Canadian chemical companies have restructured and have become leaner and meaner and they now are in much better shape to contend with a faltering economy.

Assuming no recession, profits in the Canadian chemical industry could rise modestly—perhaps 5 to 10%—next year. But don't look for another 50% gain. □

Chemical shipments are trending higher . . . . . . as chemical prices start to firm up



a Seasonally adjusted. Source: Based on Statistics Canada data

U.S.S.R./Eastern Europe

Soviet bloc pushes reform of industrial planning and control

Chemical industry has key role in providing intermediates and end products needed in modernization drive

Richard J. Seltzer, C&EN Washington

Economic and industrial developments in the Soviet Union and East Europe this year are dominated by the reform process launched by Soviet leader Mikhail S. Gorbachev.

Approved in June by the Soviet Communist Party Central Committee and in July by the Supreme Soviet (the nominal legislature), Gorbachev's reform package calls for far-reaching perestroika (restructuring or transformation) in Soviet planning and management. The aim is to replace centralized, directive management of economic or industrial enterprises with more decentralized decision-making, open up a greater role for such market incentives as prices, wages, and profits, and slim down the bureaucracy.

The key element, the Law on State Enterprise, goes into effect Jan. 1, and its provisions will fully cover all enterprises by the start of the next five-year plan in 1991. This law establishes the state enterprise or association as the basic economic unit—self-financing, self-managed, and dealing with other units on the basis of contracts and full economic accountability. Profit is to become the main indicator of economic performance.

To varying degrees, the U.S.S.R.'s six East European allies—Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania—are also considering or undertaking reform programs. In the near term, reform efforts are likely to generate much confusion and controversy, and even to impede economic growth in the Soviet Union and East Europe, notes a study by WEFA Group (formerly Wharton Econometric Forecasting Associates). Polish voters have just rejected a reform program calling for austerity measures, for instance. Tangible boosts to growth may not appear until the early 1990s, WEFA adds. Tightening energy supply and hard-currency debt problems act as a spur to improve productivity and export competitiveness.

Chemical production plays a key role—supplying intermediates and many end-products required by the industrial modernization drive. Nations of the region thus give high priority to their chemical industries. Except for Czechoslovakia, their five-year plans (1986–90) target faster growth for chemicals than for industry as a whole.

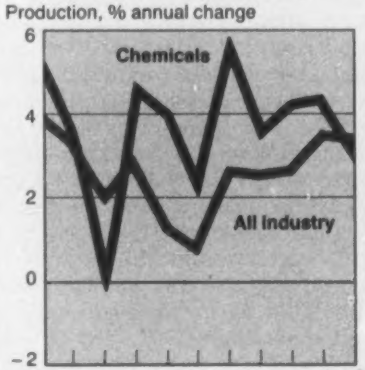
The Soviets, for example, have adopted a comprehensive program for "chemicalization" of their economy by the year 2000. Chief targets include plastics for the machine-building and construction industries; synthetic fibers for textile, tire, and other industries; multinutrient fertilizers and advanced pesticides for agriculture; and advanced products for use in microelectronics and optics. Soviet chemical output is to increase a third by 1990, compared with 1985, and industry overall is to grow only about a quarter.

Like other nations in the region, Poland's five-year plan seeks to change the structure of industrial production. It is trying to shift away from energy- and material-intensive products, increase productivity and "thrift and inventiveness inside enterprises," enhance worker incentives, introduce new technology, raise product quality, and direct a larger proportion of its production toward export.

Poland's chemical industry is to raise output nearly 5% in 1988, higher than any other branch (industry overall is to grow 4%). Greatest chemical growth will come in pharmaceutical production, to rise 10%. Output of several new commodities will start, including pentaerythritol (in facilities with a 4000 metric tons-per-year capacity), formic acid (2000 metric tons-per-year capacity), and cyclohexylamine (2000 metric tons-per-year capacity).

Czechoslovakia gives high priority to development of "small-volume chemistry," targeting higher value-added, sophisticated chemicals. Its goal is a 13% rise in chemical output by 1990, or 2.4% a year from 1986 to 1990. This is slightly below

Chemical output generally has outpaced all industry



a Preliminary. b For first 10 months; official Soviet figure for 1987 is for chemical and timber industries, rather than just chemical industry. **Sources:** Central Intelligence Agency, U.S.S.R. State Committee for Statistics for 1987 (CIA estimates for years prior to 1987 are lower than official Soviet statistics)

Chemical output up in U.S.S.R. but mixed in East Europe

Thousands of metric tons, 1986	U.S.S.R.	Bulgaria	Czechoslovakia	East Germany	Hungary	Poland	Romania
Mineral fertilizers^{a}	34,700	674	na	5046	1040	2526	na
Change from 1985	4.5%	5.1%	na	4.2%	−2.4%	11.3%	na
Nitrogen (N)	15,200	541	614	1252	584	1445	na
Change from 1985	6.9%	15.4%	16.7%	16.1%	−3.3%	15.2%	na
Phosphate (P_2O_5)	9,100^{b}	132	307^{b}	309	163	948	na
Change from 1985	5.9%	−23.0%	−1.0%	3.3%	25.4%	6.6%	na
Potassium (K_2O)	10,400	—	na	3485	293	133	na
Change from 1985	0.3%	—	na	0.6%	−12.0%	4.7%	na
Sulfuric acid, 100%	27,900	806	1292	883	543	2969	na
Change from 1985	7.2%	−0.5%	−0.4%	0%	4.4%	3.7%	na
Ammonia^{c}	19,400	na	na	1197	762	na	na
Change from 1985	6.4%	na	na	−1.1%	−3.5%	na	na
Plastics	5,344^{d}	na	1140	1045	423	631	na
Change from 1985	6.5%	na	3.4%	−0.3%	8.7%	4.6%	na
Sodium hydroxide,	3,229	144	335	638	202^{e}	427	na
Change from 1985	5.7%	−4.6%	0.9%	−4.3%	4.1%	3.1%	na
Synthetic rubber	2,250	26	76	130	56	116	162
Change from 1985	5.9%	0%	8.6%	−7.1%	27.3%	−7.9%	3.8%

a Nutrient content basis. b Includes ground phosphate rock for direct application and phosphate animal feeds. c Nitrogen content. d Includes resins for man-made fibers. e Includes regenerated NaOH. na = not available. **Sources:** Central Intelligence Agency, WEFA Group (formerly Wharton Econometric Forecasting Associates), Foreign Broadcast Information Service, state central statistical bureaus

the goal of 3% a year for all industry. However, production of organic dyes, fine chemicals, pesticides, and pharmaceuticals is to grow at least 40% each by 1990, with the aim of "markedly strengthening the export ability in these branches."

East Germany's five-year plan seeks to raise plastics output 117% by 1990, emphasizing materials for microelectronics, metal processing, construction, and consumer goods industries. Synthetic fiber production is to grow 132%, with corresponding stepups in production of acrylonitrile, terephthalic acid, and caprolactam. And for the first time, East Germany will produce "highly refined special product ranges of carbon and aramide fibers" for strengthening polymer compounds. Between 1986 and 1990, East Germany also plans to increase chemical plant construction 7% a year.

Economic results this year make it unlikely that the Soviet Union and most East European nations will meet their 1987 targets, also casting doubt on achievement of their overall five-year goals. Growth of industrial production slowed this year for most countries of the region. Severe winter conditions depressed first-quarter activity, but social unrest and structural bottlenecks also hamper growth in several nations.

Soviet industrial output was up 3.4% for the first 10 months of 1987, compared with the same period in 1986. This falls below the target of 3.8% for all of 1987, and is a considerable drop from the 4.9% growth achieved in all of 1986, according to official statistics. (Preliminary figures from the Central Intelligence Agency list just 3.6% growth for 1986, after eliminating what it considers upward bias due to double counting and hidden inflation.) Moreover, the Soviet goal for 1987 already was short of the 4.6%-a-year growth set by the five-year plan.

Growth of the Soviet chemical industry and timber complex also slowed to 2.9% through October. Production of plastics, sulfuric acid, and ammonia fell short of target, as did output of chemical and oil field equipment.

Total industrial output for the six East European nations rose 2.9% in the first half of 1987, according to a report by the United Nations Economic Commission for Europe, based on official statistics. This falls short of the reduced goal for 1987 of 4.1% and the five-year plan target of 4.4% a year and is well below the rise of 4.7% achieved in all of 1986.

Bulgaria, for example, raised industrial production 3.5% through September, well short of the 1987 goal of 4.9%. The chemical and biotechnology industry grew only 1.1%. Poland's chemical industry grew 3.6% through August (the goal for the year is 4.7%).

However, Hungary's chemical industry is "an island in the slightly stormy sea of the people's economy," as a Hungarian newspaper puts it. Output rose 6.3% through August (overall industrial output rose just 2.9%). Chemicals provided 20% of all industrial production and were the leading export. Chemical exports in hard currency are expected to rise $100 million (16%) this year.

Romania continues to set very high growth targets (6 to 7% overall industrial growth and 8.9% chemical growth for 1987). It claims chemical growth rates of 18% a year between 1965 and 1985. However, it now publishes almost no statistics, and the reliability of what it does release is questioned. Nevertheless, Western analysts conclude that it is having another bad year, following poor years in 1985 and 1986. Industrial output grew just 1.1% through June, and chemical output fell 6%.

As for future prospects for the Soviet Union and Eastern Europe, many Western analysts once believed that Gorbachev, like previous Soviet leaders, would at most tinker with the system to make it work better. They did not think he would seek the fundamental structural changes they view as necessary to meet Soviet needs and goals.

Now, however, there is wide agreement that Gorbachev is serious about carrying out fundamental reforms. The question is whether he can overcome the many forces and interests opposing such changes. "Even with the best of efforts, this reform is unlikely to be fully implemented until the mid-1990s, and that is optimistic," notes Ed A. Hewett of the Brookings Institution, a specialist on the Soviet economy. In the meantime, some observers believe, the reforms must yield some economic and industrial progress in the Soviet Union and Eastern Europe, or the political survival of Gorbachev and other reformers would be endangered. ☐

Mexico

Chemical industry is putting more emphasis on exports

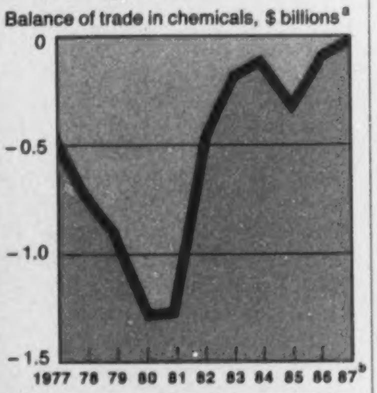
Weakening peso will make chemicals more competitive but also will increase the cost of imported feedstocks

Earl V. Anderson, C&EN New York

By most accounts, last month's precipitous plunge in the "free rate" of exchange of the Mexican peso will do little, if anything, to stymie the progress that the country's chemical industry has been making in increasing output, boosting exports, and substituting domestic production for imports.

The free-rate peso accounts for only about 20% of Mexico's foreign currency transactions, mostly those by tourists and businesses along the U.S.-Mexican border. The bulk of the country's transactions, including most exports and imports, takes place at the official "controlled" rate, which was not affected when the Bank of Mexico removed its support for the free-rate peso.

Chemical trade deficit is shrinking fast



a Private sector chemical trade only; does not include petrochemical trade of Petróleos Mexicanos (Pemex). **Source:** ANIQ (Asociación Nacional de la Industria Química)

Realistically, however, some fallout is bound to hit the Mexican chemical industry. When the Bank of Mexico removed its support last month, the free rate dropped from about 1700 to the U.S. dollar to a range of 2300 to 2500. The controlled rate remained at about 1728 pesos per dollar. But analysts doubt if it can remain that much lower for long. If the controlled rate does, in fact, start declining more rapidly, Mexican products will be less expensive, hence more competitive, in world markets, particularly in the all-important U.S. market.

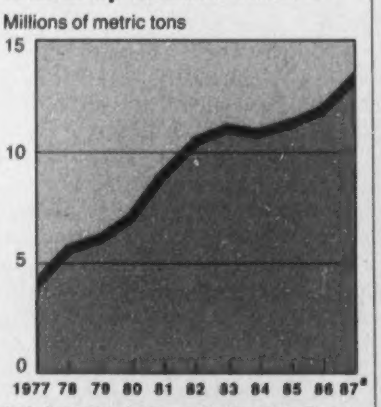
That would be good news for the Mexican chemical industry, which is pushing exports as avidly as any industry in the country (C&EN, Oct. 26, page 11). Mexico's private chemical sector exported just over $1 billion worth of chemicals last year, 35% more than in 1985. This helped reduce the private sector's chemical trade deficit to only $95.6 million, down from a hefty $342 million the year before. And Leopoldo Sanchez, president of ANIQ, Mexico's chemical industry trade association, thinks that the private sector chemical trade deficit may disappear completely this year.

For Mexico's chemical industry, however, a sharp drop in the peso's controlled rate of exchange has a dark side as well as a bright side. Many of the chemicals that private Mexican companies export are made with imported raw materials. And because Petróleos Mexicanos (Pemex), the government oil and petrochemical company, stopped importing basic petrochemicals on behalf of the private companies last year, the private companies now must do their own importing.

A weaker peso makes Mexican exports less expensive, but it will make imports more expensive. Just how much of an impact this may have on the chemical industry's export ambitions remains to be seen.

Meanwhile, Pemex is moving ahead with its petrochemical plant-building program, designed in large part to keep imported feedstock requirements to a minimum. Construction on the first phase of its huge Morelos complex is expected to be completed by the end of the year, with the plants on stream during the first quarter of 1988. This phase includes plants to produce ethylene, ethylene oxide and glycol, high-density polyethylene, and acetaldehyde. Pemex expects the entire Morelos complex to be completed by 1991, adding capacity for propylene and its derivatives, butadiene, and other petrochemicals. □

Basic petrochemical output chalks up another record

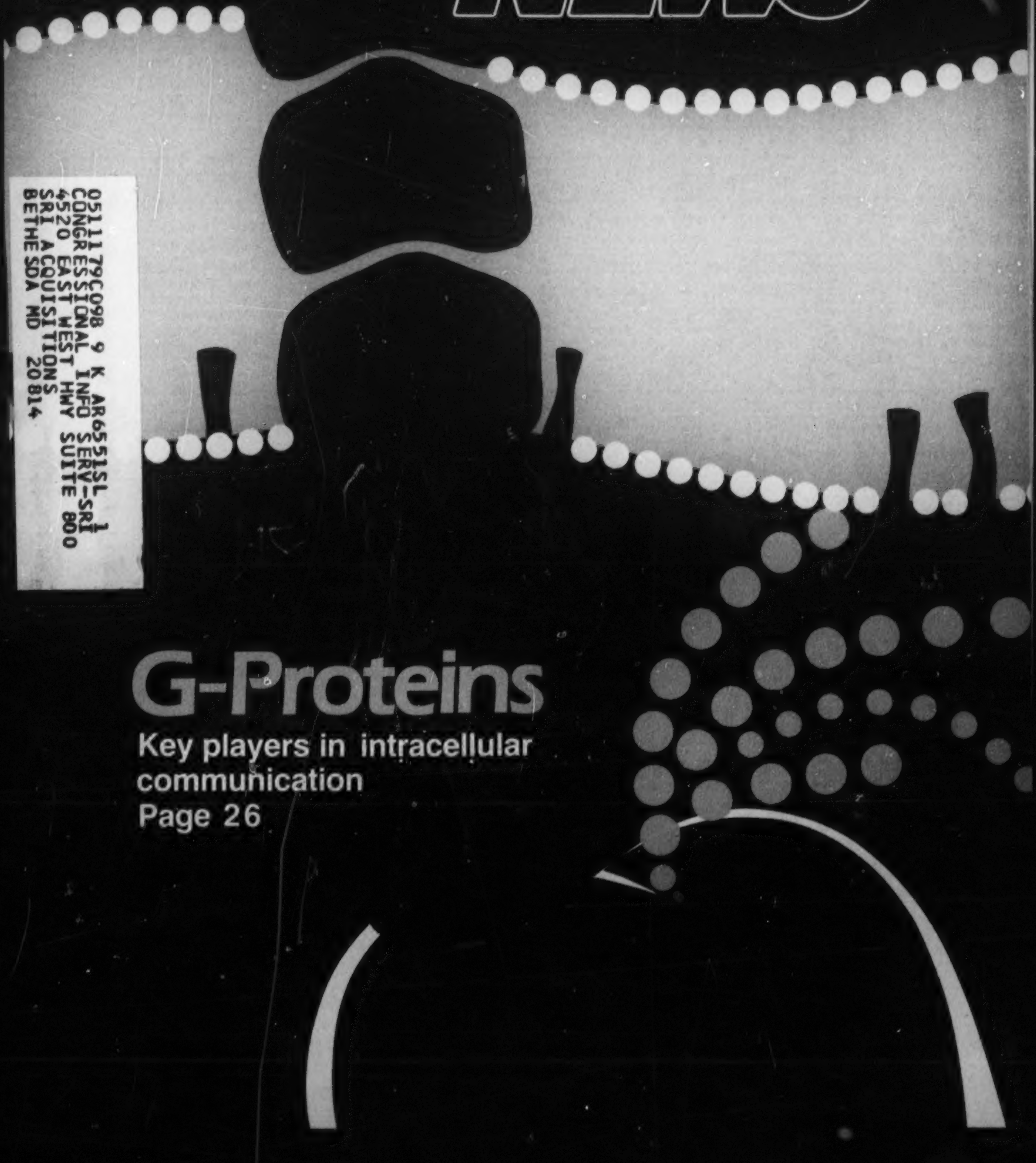


Note: Production of primary petrochemicals by Pemex only; does not include secondary petrochemicals produced by the private sector. a C&EN estimate. **Source:** Petróleos Mexicanos (Pemex)

A1250-1
12/21/87

DECEMBER 21, 1987

CHEMICAL & ENGINEERING
NEWS



05111 79C098 9 K AR65515L 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

G-Proteins

Key players in intracellular communication
Page 26

CHEMICAL & ENGINEERING NEWS

Volume 65, Number 51
CENEAR 65 (51) 1–72
ISSN 0009-2347
DECEMBER 21, 1987

News of the Week

- **Final text of U.S.-Canada free trade agreement issued by U.S. Trade Representative faces scrutiny of chemical industry and Congress. Page 4**
- **Problem of lead contamination of drinking water is being investigated by EPA. Page 5**
- **Hires of new college graduates by large U.S. firms will increase about 10% in 1988, reflecting firms' confidence in continued economic growth. Page 5**
- **In Bhopal case, Union Carbide is ordered to pay $270 million as interim sum for the relief of victims of the December 1984 disaster. Page 6**
- **NMR screening test to detect cancer is stirring growing controversy among scientists who say they have not been able to confirm its validity. Page 6**

Cover: Artist's conception of inositol phosphate communication pathway, one of several involving G-proteins. Design courtesy of National Institutes of Health

Letters 2

Concentrates
Business 7
Government 12
Science/Technology 15

The Departments
ACS News 40
New Products 42
Awards 45
Newscripts 72

Business

Capital expenditures by U.S. industry are slated to increase 20% in 1988, as rising exports keep capacity use high. **Page 9**

Government

Clean Air Act amendments approved by Senate set stricter limits on toxic air pollutants, stricter controls on acid rain precursors. **Page 13**

Tighter controls on handling and disposal of polychlorinated biphenyls would be set by House bill. **Page 14**

Technology

Chem Show, held recently in New York City, showcased the state of the art in commercial process equipment and instrumentation. **Page 16**

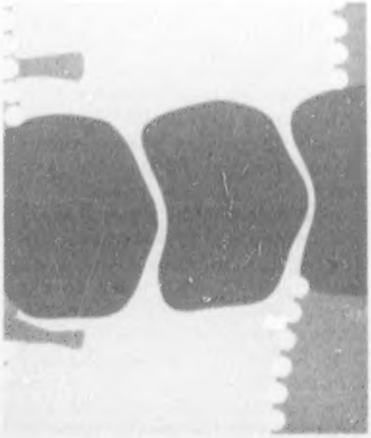
Automated DNA amplification system reduces time needed to make microgram quantities of genetic material. **Page 24**

NASA is considering converting space shuttle external fuel tank into housing for an orbiting telescope. **Page 24**

Proposed guidelines for AIDS clinical lab workers are issued by the National Committee for Clinical Laboratory Standards. **Page 25**

Meetings

Deadlines and topics for ACS meetings in fall 1988, spring 1989, and later dates are included; C&EN's semiannual calendar of meetings and events lists those of interest to chemists, chemical engineers. **Page 46**



Special Report

G-Proteins—guanine-nucleotide-binding-proteins—that couple receptors to enzymes to elicit a response within the cell are prominent area of research in cellular communication and are linked to several major diseases. Page 26

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson; Chicago: Joseph Haggin; Washington: Lois R. Ember, Rebecca L. Rawls
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Doron Dagani, Bette Hileman, Richard J. Seltzer, Pamela S. Zurer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Patricia Oates (Administrative Assistant)
News Bureaus: New York: (212) 697-3223 Stephen C. Stinson (Associate Editor), Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Associate Editor). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Donald F. Hornig, Isabella Karle, Dorothy Nelkin, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter, Richard N. Zare

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Barbara G. Wood (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Mary L. Good; E. E. McSweeney; John H. Nelson; Louis D. Quin; and Jean'ne M. Shreeve

© Copyright 1987, American Chemical Society

Subscription Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1987. Printed editions: nonmembers U.S. 1 yr. $44, 2 yr. $75, outside U.S. 1 yr. $70, 2 yr. $127. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $6.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 71)

LETTERS

CAS billing changes

SIR: The changes that Chemical Abstracts Service plans to make in billing for use of its on-line databases (C&EN, Sept. 28, page 44) are wrong and should be reconsidered.

CAS would reward inefficient use of its databases by penalizing efficient users with its new fees. On the surface, what CAS proposes seems eminently reasonable, the new fees being assessed to approximate the value of the information obtained. Ultimately, however, the fees and the policy behind them would harm not only CAS's present users, but also U.S. chemical science and industry.

It is supremely ironic that an arm of a professional society avowedly seeking to advance chemistry would implement this antitechnology fee schedule. As a patent attorney who occasionally accesses the CAS databases, I presumably would benefit from the proposal, my unsophisticated search techniques and constant references to the database manual subsidized by the higher fees CAS will extract from professional searchers. Fortunately, I'll never need to learn new search techniques or buy more sophisticated software; CAS will protect me from both.

Alex R. Sluzas
Philadelphia

Chemical Abstracts Service's response: Alex Sluzas correctly identifies technology as the single most important consideration underlying our new pricing policy, but incorrectly concludes that the new fee schedule is antitechnology. CAS continually endeavors to introduce new technology that lightens the task of the searcher, and strongly encourages others to do likewise. If some such technology also has the effect of substantially reducing the amount of connect-time required to conduct a search, this does not speak against the technology itself, but against the use of connect-time as a viable basis for charging.

As a database producer, CAS's primary pricing objective is to receive sufficient revenues from on-line searching to help defray the costs of building the database. We agree with Sluzas' conclusion that the new pricing policy will benefit less sophisticated searchers, and we believe it will benefit professional searchers as well. The new policy is aimed at measuring use of the database in ways that are independent of the technology employed, thus providing more flexibility for the introduction of important new technology, while preserving the revenue base required to conduct the business of the society.

Harry Boyle
CAS, Columbus

Issues for ACS publications

SIR: Polemics are not my style, but Andrew Pudzianowski's 20-column-inches of prose (C&EN, Oct. 12, page 2), which purports to comment on my letter (C&EN, July 20, page 5), deserves one or two footnotes.

I did not state, suggest, or imply that scientists should not participate in debate on political, social, economic, or technological issues. I did suggest that when they do so, that they find a forum other than ACS publications. For example, I happen to feel strongly about certain activities of the American Civil Liberties Union but I do not expect C&EN to carry discussions of these issues even though they are of great concern to scientists.

With regard to the axiom that experts are not qualified to make decisions, the key word is decisions. Good managers are generalists who listen to experts then make their own decisions. Experts are by definition single-minded, limited in their view, and so forth. The litany of disastrous "solutions" by experts is long; e.g., the Aswan dam, or perhaps the green revolution. The point also is illustrated in a comment made by one of the names Pudzianowski drops. In a conversation, one of us pointed out that a certain well-known, able administrator was a chemist. He said, with a twinkle in his eye, "Yes, but he was a bad chemist."

The really offensive aspect of some scientists who enter the public arena is the open or thinly disguised elitism. The implication is that anyone with a technical degree is larger than life. Again, I'll illustrate from my experience. A physicist was visibly offended during debate of an environmental issue when I suggested that he was entitled to one vote, as we all were.

What becomes tiresome is the preoccupation with "cosmic" issues; e.g., nuclear war or nuclear energy. Everyone who knows that atoms are fissionable is an immediate expert on nuclear war. My experience includes rocket technology, so naturally I must be an expert in missile warfare! In contrast, where are the people rushing to solve the problems of ACS? For example, the issue of fraud in research is very real. By all accounts the academic types are running—running for cover, that is. They would like to see George solve this problem. Obviously it

Chemical Capital Spending To Jump 20% in 1988

Rising exports are keeping capacity use high, have helped spur major U.S. chemical companies to sharply boost plant and equipment spending

Marc S. Reisch, C&EN New York

Capital expenditures by U.S. industry will show a healthy increase in 1988 compared with 1987, according to preliminary forecasts by leading chemical producers. Eleven of 12 major chemical companies surveyed by C&EN estimate their 1988 expenditures will rise 20% to $6.84 billion compared with 1987. (Du Pont, the biggest chemical capital spender, had not responded with its 1988 estimate at press time.) The 1988 forecast follows a modest 6% increase in capital spending in 1987 compared with the previous year.

Chemical producers apparently feel that, despite a weak domestic economy, their sales to foreign customers are on the upswing. According to Charles B. Reeder, head of Charles Reeder Associates and former chief economist at Du Pont, the chemical industry, like the textile and paper industries, is "running flat out." The decline in the value of the U.S. dollar has led to increased exports as well as some substitution for imported goods by domestic production. Reeder believes this trend "will continue and warrant fairly vigorous capital spending in 1988."

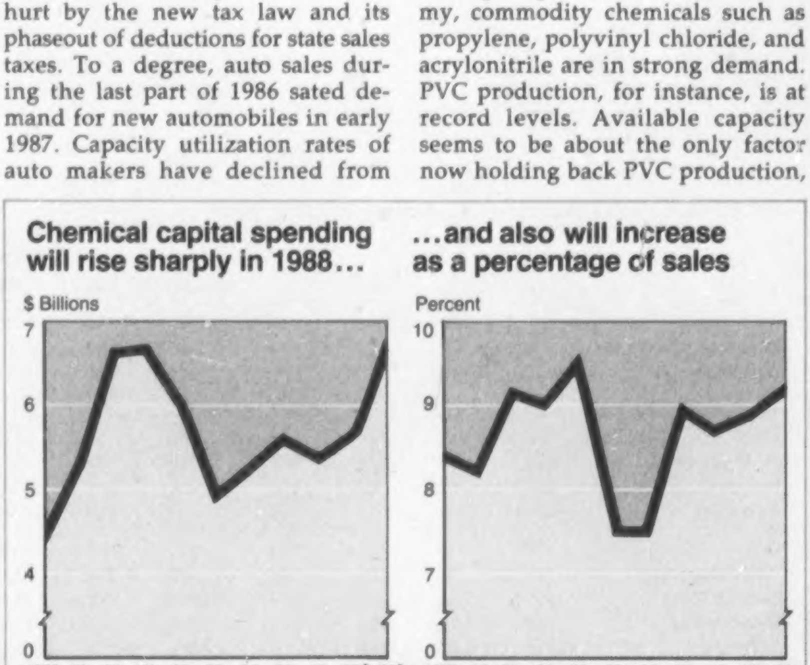
In spite of the nosedive the stock market took in October, U.S. producers continue to forecast a good fourth quarter. And most of them report strong orders and predict continued sales and profit growth into 1988. But the stock market decline does presage continued weak consumer demand.

Two of the chemical industry's big markets—housing and automobiles—remain soft. The housing market has been hurt in particular by the new federal tax law, which has eliminated many incentives to build. Housing also is slumping in certain parts of the country where local economies are under siege. In Houston, for instance, the oil industry is still under pressure because of low energy prices. The recent stock market decline also has slowed office construction demand in New York City, center of the financial service industry, as banking and trading concerns trim their expansion budgets and personnel needs.

The auto industry also has been hurt by the new tax law and its phaseout of deductions for state sales taxes. To a degree, auto sales during the last part of 1986 sated demand for new automobiles in early 1987. Capacity utilization rates of auto makers have declined from about 80% late in 1986 to 62% in August 1987, according to statistics compiled by the Federal Reserve Board. More recent figures show only a modest recovery for auto production to 73% in October. Economists say that consumer demand is unlikely to pick up for automobiles anytime soon, particularly as consumers remain cautious following the recent drop in stock prices.

As for a third major market—agriculture—economists see slightly better prospects for the domestic farm economy next year. However, agricultural chemicals show strength only in specific product lines. High yields, poor demand, and foreign competition continue to dog farmers and the agricultural chemicals business.

Despite problems in the economy, commodity chemicals such as propylene, polyvinyl chloride, and acrylonitrile are in strong demand. PVC production, for instance, is at record levels. Available capacity seems to be about the only factor now holding back PVC production,


Chemical capital spending will rise sharply in 1988...

...and also will increase as a percentage of sales

Note: Combined data from 12 major chemical producers listed on page 10. a C&EN estimates.

forecast to grow 2 to 4% in 1988 (C&EN, Dec. 14, page 9). And while commodity prices spiral upward on steadily increasing demand, feedstock prices remain stable as oil prices promise to remain level or even decline.

All this bodes well for exports. In fact, export volume has grown steadily ever since the dollar began its steady decline, points out Reeder. The U.S. trade deficit has increased only as more depreciated dollars are needed to pay for the relatively lower volume of imports coming into the country now than at the same time last year, he says.

With stable and even declining oil prices expected in the months ahead, as well as the modest wage increases workers have received in recent years, chemical producers are betting that 1988 will be an excellent year for exports. This will keep capacity utilization high and will help fuel the dramatic increase in plant and equipment spending planned for 1988 by the major chemical producers surveyed by C&EN.

The 6% increase in capital spending in 1987 compared with 1986 was a lot better than the less than 1% increase predicted in last year's survey (C&EN, Dec. 22, 1986, page 9). Estimated 1987 capital spending for a number of companies was higher than the industry as a whole planned last year. W. R. Grace increased expenditures 38% to $275 million. The hike reflects the increased emphasis Grace is placing on the specialty chemical businesses since the company spun off its retailing and restaurant operations.

Du Pont boosted its capital spending 13% in 1987 to $1.8 billion compared with expenditures a year earlier. Increasing their spending about 12% were PPG Industries and Rohm & Haas. PPG's expenditures rose to $400 million and Rohm & Haas' to $200 million. Dow Chemical and American Cyanamid increased their spending at a more modest rate: Dow 9% to $970 million and Cyanamid 4.6% to $275 million.

Other chemical producers barely kept up with inflation or saw their capital expenditures decline in 1987. While Monsanto increased its 1987 spending a meager 1% to $525 million, Air Products drew back 0.3% to $366 million, and Olin decreased its capital expenditures 4.7% to $122 million from its 1986 spending level. Union Carbide reduced its spending 6.5% to $490 million. And Hercules dropped its investment in plant and equipment a huge 22% to $200 million.

Nine of the 12 chemical producers plan double-digit increases in their capital spending in 1988. The exceptions are Air Products, which is forecasting a 9.3% rise from this year in its expenditures to $400 million, and Monsanto, which plans to cut its spending 2.3% next year to $513 million. Rohm & Haas plans the biggest increase in 1988, 50% to $300 million. Other large increases are planned by Grace, up 46% to $400 million; Olin, up almost 30% to $158 million; and American Cyanamid, up 27% to $350 million.

Hercules plans a dramatic 25% increase in capital expenditures to $250 million following a large decline the year before. David S. Hollingsworth, chairman of the large chemical and aerospace concern, has stated that Hercules has completed the series of divestitures that culminated in its recent sale of a 37.5% interest in polypropylene producer Himont to Montedison. His assertion that "now it is time to grow" (C&EN, Oct. 12, page 9) may be fulfilled in Hercules' forecast 1988 capital expenditures increase.

Dow Chemical also plans a huge increase in capital expenditures with $1.2 billion earmarked for capital improvements, a 24% hike over this year's investment and the first time since 1981 that the company's total planned improvements will exceed $1 billion.

Others planning sizable boosts in their investment in plant and equipment include Union Carbide, with an 18% increase to $580 million compared with this year, and PPG, whose 13% increase to $450 million is pretty much in line with its increase in the level of spending this year.

These companies' capital spending in the U.S. will lag worldwide capital spending only marginally in

Chemical capital spending will soar next year

	1988		1987		Worldwide					Change from previous year	
$ Millions	Total	U.S.	Total	U.S.	1987 planned[a]	1986	1985	1984	1983	1988	1987
Air Products[b]	$ 400	$ 227	$ 366	$ 217	$ 400	$ 367	$ 392	$ 263	$ 246	9.3%	−0.3%
American Cyanamid	350	280	275	220	265	263	203	200	165	27.3	4.6
Dow Chemical	1200	660	970	590	980	890	806	781	630	23.7	9.0
Du Pont[c]	na	na	1800	1400	na	1587	1515	1319	1276	na	13.4
Ethyl	150	145	130	125	145	134	90	103	85	15.4	−3.0
W. R. Grace	400	na	275	185	300	199	348	380	353	45.5	38.2
Hercules	250	215	200	170	200	257	234	218	168	25.0	−22.2
Monsanto	513	338	525	338	520	520	645	614	560	−2.3	1.0
Olin	158	na	122	na	140	128	154	165	123	29.5	−4.7
PPG Industries	450	na	400	na	400	356	452	315	450	12.5	12.4
Rohm & Haas	300	230	200	170	200	179	159	124	72	50.0	11.7
Union Carbide	580	405	490	320	525	524	649	670	761	18.4	−6.5
TOTAL	**$4751**	**$2500**	**$5753**	**$3735**	**$4075**	**$5404**	**$5647**	**$5152**	**$4889**		
ANNUAL CHANGE[d]	**20%**	**16%**	**6%**	**5%**		**−4%**	**10%**	**5%**	**−19%**		

a Earliest estimates. b Fiscal year ends Sept. 30. c Excludes Conoco. d Cumulative change for companies reporting. na = not available.

1988. The 11 companies responding to the C&EN survey estimate U.S. capital spending will rise an average of 16% compared with 20% worldwide. This follows capital expenditure increases of 6% worldwide and 5% in the U.S. in 1987.

Growth in capital spending has been fairly stagnant over the past few years, according to Myron T. Foveaux, trade and economic policy adviser for the Chemical Manufacturers Association. C&EN's surveys pretty much support this observation. Industrywide, Foveaux says, capital investment has grown only 4.5% annually over the past five years and, for the past three years, total chemical industry capital expenditures have hovered around $16.5 billion.

Foveaux says that his survey of chemical producers, conducted last month, indicates that they plan to increase capital expenditures an average 14% in 1988 over this year. Based on the survey, he forecasts that firms will spend about 10% of the total outside the U.S. during 1988. About 36% of investments will go to new facilities. And about 16% will be used to achieve compliance with environmental control regulations.

Chemical producers are unlikely to spend much on new petrochemical plants, Foveaux adds, in light of the large number of petrochemical plant shutdowns over the past five years. He believes that most new plant spending in 1988 will be for facilities to produce specialty products.

Foveaux cautions that, though chemical industry exports are expected to reach a record $26 billion this year, up 14% from 1986, imports also will be up markedly—5% over last year to a record $15.8 billion. The U.S. chemical industry probably will show a favorable trade balance of $10.3 billion for 1987, says Foveaux. Still, he adds, this is a far cry from the $12.2 billion trade balance the chemical industry recorded in 1980. □

West German chemical giants are bullish on U.S.

Though West Germany's three largest chemical companies forecast only a modest increase overall in their capital expenditure programs, they plan a rather hefty increase in their U.S.-based assets.

BASF, Bayer, and Hoechst combined plan a worldwide increase of 7% in 1988 capital spending to nearly $5 billion compared with this year. However, as a group they plan to increase expenditures in their U.S. operations 23% to $925 million.

This increase in capital spending is even larger than the 16% rise forecast by U.S.-based chemical producers. The West German giants, it would seem, are even more optimistic about prospects for their U.S. operations than their U.S.-based competitors are about their own domestic prospects.

The 23% increase, in part, reflects the fact that the dollar is cheaper than it was a year earlier. For comparison, capital spending figures for the three companies are based on a conversion rate of $1.00 = 1.6 deutsche mark for both 1987 and 1988. U.S. spending figures were supplied by the firms in U.S. dollars. Also for comparison, Hoechst's figures include Celanese's capital expenditures in 1986 when Celanese was not yet owned by Hoechst.

Bayer plans the largest increase in its 1988 spending with a forecast 13% rise to $1.7 billion worldwide. BASF is second with a 7.1% increase to $1.9 billion. Hoechst does not plan any increase in 1988.

	1988		1987		Change from previous year	
$ Millions[a]	Worldwide	U.S.	Worldwide	U.S.	1988	1987
BASF	$1875	$315	$1750	$260	7.1%	3.7%
Bayer	1687	260	1500	220	12.5	0
Hoechst	1437	350	1437	270	0	9.5
TOTAL	$4999	$925	$4687	$750		
ANNUAL CHANGE	7%	23%	4%	20%		

a $1.00 = 1.6 deutsche marks.

Another item for your

LANTHOLOGY

of Ln's in modern chemistry*

Out of this California mine...

LANTHANIDES AND YTTRIUM, THE PRECURSORS OF TOMORROW'S SUPERCONDUCTORS

as aggressive research commercializes new-age...

NMR DIAGNOSTIC IMAGING
POWER GENERATION & STORAGE
COMPUTER & VLSI INTERCONNECTS
MAGNETIC SHIELDING & SQUIDS
COMPACT MOTORS & BATTERIES
NON-CONTACT BEARINGS
ULTRASENSITIVE I-R DETECTORS

Over three decades this open-pit bastnasite mine, and the four processing plants it serves,* have supplied more than half of the world's need for the lanthanides (Y, La, Nd, Sm, Eu, Gd, Dy, Ho etc.)—the very elements essential to the new copper-oxide ceramic superconductors. And there's enough ore remaining for decades to come.

Write for specifications; phone for technology. 1554

*Currently in a 4-step 5-year $10 to $20 million expansion.

UNOCAL 76
MOLYCORP

MOLYCORP, INC. • A Unocal Company
709 Westchester Ave., White Plains, NY 10604
Tel. 914/997-8880 • TWX 710/568-0305

* The lanthanides and their companion, Y—the "rare earths"—are separated by solvent extraction and offered as oxides, compounds or metals.

THE LANTHANIDE SERIES

CIRCLE 12 ON READER SERVICE CARD

A1250-1
1/6/88

Pressure builds on Carbide in Bhopal litigation
Page 8

JANUARY 4, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR6601SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Gordon L. Nelson
ACS President
Page 2

Volume 66, Number 1
CENEAR 66 (1) 1–56
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

JANUARY 4, 1988

News of the Week

- **Of R&D agencies, NSF is one of those hard hit by the fiscal 1988 budget agreement worked out by Congress and the White House in December. Page 6**
- **Biochemical defect that causes Duchenne muscular dystrophy, the most common and deadly form of the disease, has been identified. Page 7**
- **Beleaguered pharmaceutical firm A. H. Robins receives two new merger bids and Rorer sweetens its existing agreement with Robins. Page 7**

Business

Ethanol producer Bio-Regional Energy Associates investigates use of hardwoods as raw material in effort to reduce financial risks. **Page 14**

Government

Environmental priorities of Superfund skewed by EPA management's bureaucratic goals, Office of Technology Assessment official tells Senate subcommittee. **Page 17**

"Key technologies for the 1990s"—a national program that would involve a cooperative effort by industry, government, and academia—aims to return technological leadership to U.S. **Page 18**

Science

Initial research into sequence-specific DNA recognition reveals that synthetic molecules can recognize specific DNA sequences up to 15 base pairs in length. **Page 20**

Total synthesis of avermectin, a glycoside precursor of ivermectin, is achieved by Yale research team. **Page 26**

ACS News

Chairmen for several major ACS committees were selected at the board of directors' meeting in Columbus, Ohio, last month. **Page 31**

Cover: Photo by C&EN's Ernest L. Carpenter

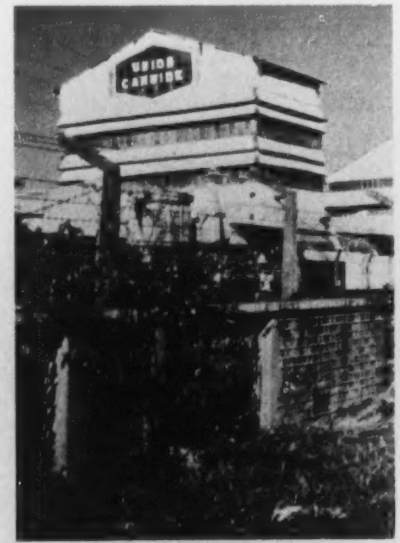
President's Message 2
Letters 4
Editor's Page 5

Concentrates

Business 13
Government 16
Science/Technology 19

The Department

Newscripts 56



News Focus

Three-year battle between Union Carbide and Indian government over liability and compensation in December 1984 gas leak disaster in Bhopal enters critical phase as Carbide faces key decisions on criminal trial, $270 million interim relief order. Page 8

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Patricia Oates (Administrative Assistant)
News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; and four additional members of the Society Committee on Publications yet to be appointed

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

CHEMICAL SAFETY

Explosion involving 3-amino-5-methyl isoxazole

SIR: Recently in a fine chemicals factory a drum containing about 100 kg of 3-amino-5-methyl isoxazole exploded. The product was prepared from 3-carboxyamido-5-methyl isoxazole with sodium hypochlorite (Hofmann reaction). After extraction with dichloromethane and distillation of the solvent, the product was transferred as a melt at 70 to 80 °C in two 200-L drums. After about two hours one of the drums exploded.

The same sequence of operations had been previously run several times without any accident. To find the cause of the accident this institute has studied the thermal stability of the product.

Samples from the batch involved in the accident have shown a differential scanning calorimetry purity of 96%, samples from previous batches 98%. Thin-layer chromatography analysis has shown the presence of the isomer 5-amino-3-methyl isoxazole as main impurity.

Thermal stability tests in the adiabatic calorimeter ARC have shown the fundamental role played by the impurities in the accident. In fact, samples taken from the batch involved in the accident decompose exothermally at 62 °C; samples from previous batches decompose at 106 °C. A reagent grade sample (Fluka, purity 99%) decomposes at 140 °C.

The decomposition of all the samples involves a substantial evolution of heat (about 1800 joules per g) and of gases.

The accident can be clearly attributed to the exothermic decomposition of 3-amino-5-methyl isoxazole transferred as a melt at 70 to 80 °C, containing amounts of impurity higher than in previous batches. The self-accelerating heat evolution and the rate of pressure increase from gases in quasi-adiabatic conditions caused the burst of the drum.

Paolo Cardillo
Stazione Sperimentale per i Combustibili
Milan, Italy

Building more barriers

SIR: Lots of chemists these days—including some who write letters to C&EN—derive good clean fun from complaining how little chemistry is appreciated by the press and public. Certainly chemistry has some special problems, but part of its status just reflects the public's poor general scientific literacy.

No doubt about it; science can be tough to put across, and the areas furthest from everyday experience are the toughest, so one might suppose scientists would be anxious to remove unnecessary obstacles. It seems odd to me, then, that they are busy building more barriers by taking experientially named, self-explanatory scientific units and giving them new honorific names, which convey nothing at all to the uninitiated. This is called jargon.

Put yourself, if you can, in the place of that "man in the street," who has, perhaps, some modest smattering of science, and compare what is conveyed to you by the following: cycle ~~per~~ second vs. hertz; centigrade vs. Celsius; atomic mass unit vs. dalton; millimeters (of mercury) vs. torr(icelli).

With the greatest respect for those whose names are being appropriated, I really object to honorific changes of this sort. They seem noble, but they are not like issuing a commemorative stamp: Something important is being lost. If you are going to collude in and accept this kind of stuff, please don't come to me with sob stories about how the public doesn't understand you.

Hugh W. Thompson
Professor of Chemistry
Rutgers University

B.S. and M.S. chemists

SIR: I am sorry that Horst Kehl (C&EN, Nov. 2, 1987, page 2) was insulted by the report (C&EN, Sept. 28, 1987, page 24) of my remarks at the recent ACS symposium on Ph.D. education in chemistry. I surely had no intention of offending him or the thousands of professional M.S., B.S., and B.A. chemists.

The problem is largely, I think, one of the context of my remarks; I was talking specifically about the initiation and direction of chemical research programs, especially in colleges and universities, where the research experience of a Ph.D. is an important factor for success. There are also many other worthy professional careers in chemistry, as Kehl points out. With the image of the chemistry profession under fire in the world at large, we cannot afford to be divided by misunderstandings. I apologize to the many fine M.S. and B.S. chemists who may have been offended by the report of my remarks. A subsequent paper in the *Journal of Chemical Education* will clarify my views.

Jerry R. Mohrig
Northfield, Minn.

FEDERAL R&D BUDGET: Among agencies, NSF fares poorly

The National Science Foundation appears to be the civilian research agency hardest hit by the fiscal 1988 budget agreement worked out in late December between Congress and the White House on reducing the federal deficit.

The Administration had requested an 18% funding increase for NSF last January and committed itself to doubling NSF's budget over five years. The Senate had approved the full amount. The House had allowed a smaller, but still significant, increase. Then the stock market crashed in October, leading to the deficit reduction agreement.

On paper, NSF will get a 6%, $95 million increase to $1.7 billion in fiscal 1988. Funding for science education will be up 40% to $139 million. However, funding for research and related activities, which is where the grant money comes from, will be up only 3% to $1.5 billion. Once the money that Congress has earmarked for various programs and the Congressionally mandated 2% pay raise for federal personnel is subtracted from that amount, NSF will be left with 2 to 2.5% less money available for distributing grants than it had in fiscal 1987, according to NSF controller Sandra Toye.

No decision has yet been made on how the funds will be allocated to the various divisions, including chemistry. But there will almost certainly be a decline in the number of grants, as NSF tries to keep the amount of support provided by each grant from falling below the critical level. Also at question is what will happen to the new science and technology centers program. NSF has already received more than 700 letters of intent from institutions that say they will be applying for grants. It will take some time to peer review that number of proposals, so one possibility is delaying awards into the next fiscal year, which will start on Oct. 1. That, of course, depends on NSF's getting a bigger increase for fiscal 1989 than it did in fiscal 1988. NSF director Erich Bloch will be making the decisions on the S&T centers and division funding over the next few weeks.

In contrast, the Department of Energy's energy R&D programs fared very well in fiscal 1988, with funding up by over 30% to $3.2 billion. Within that overall total, funding for basic energy sciences is up 20% to $564.6 million. Funding for chemical sciences is set at $130.6 million and that for materials sciences at $172.5 million. Funding for fossil energy R&D is up 10% to $327 million, while funding for general science and research, which includes high energy and nuclear physics is up 12% to $804.5 million.

The National Institutes of Health will get an 8%, $480 million increase to $6.7 billion. That's 18% more than the Administration had requested last January. However, all but $32 million of that increase is earmarked for research on acquired immune deficiency syndrome (AIDS), leaving the rest of the NIH budget with a less than 1% increase. This could mean a decline in the number of new and competing research grants that NIH can fund in fiscal 1988, a goal the Administration has been trying to reach for some time.

Congress has more than doubled funding for AIDS programs in fiscal 1988, providing a total of $932 million. In addition to the NIH research programs, the Centers for Disease Control will get $305 million for education and prevention programs, and the Alcohol, Drug Abuse & Mental Health Administration will get $112 million for, among other things, development of programs to slow the spread of the disease through use of infected needles. Another $25 million is designated for the Food & Drug Administration, which must approve AIDS treatments, and $11 million for training of health care professionals.

R&D budgets: most up slightly in tight budget year

	1988			
$ Millions	Congressional appropriation	Administration request	1987	% change 1987–88
DOD RDT&E	**$37,067.3**	**$43,719.0**	**$36,945.0**	**0%**
NIH	**6,670.7**	**5,612.8**	**6,190.7**	**8**
DOE	**4,714.2**	**4,430.6**	**3,882.7**	**21**
Energy	3,247.3	2,954.2	2,505.5	31
Defense	1,466.9	1,476.4	1,377.2	1
NASA	**3,274.2**	**3,651.2**	**3,127.7**	**5**
NSF	**1,717.0**	**1,892.5**	**1,622.1**	**6**
Research & related activities	1,453.0	1,634.5	1,406.1	3
Science education	139.2	115.0	99.0	41
Antarctic programs	124.8	143.0	117.0	7
Commerce	**1,255.0**	**1,151.9**	**1,168.0**	**7**
NOAA	1,110.0	1,013.3	1,044.6	6
NBS	145.0	138.6	123.4	18
USDA	**979.9**	**917.6**	**971.5**	**1**
EPA[a]	**186.4**	**187.6**	**202.5**	**−8**
TOTAL	**$55,864.7**	**$61,563.2**	**$52,168.1**	**7%**

[a] Does not include in-house R&D activities. Source: *Congressional Record*

Research funding for the National Aeronautics & Space Administration will be up 5% to $3.3 billion. The Administration had requested a 17% increase. Hardest hit of the NASA programs is the space station. Congress cut its funding request almost in half, allowing only $425 million in fiscal 1988. This troubles Sen. Howell T. Heflin (D.-Ala.), who says that "if we allow the space station of the U.S. to be killed, it will not be long before the entire space program of the U.S. will fall also."

The Department of Defense's R&D budget, after growing substantially for the past several years, is essentially flat in fiscal 1988. Congress held the research, development, testing, and evaluation budget to a mere $122 million, 0.3% increase. The Adminstration had requested an 18% increase. And the Administration's $5.8 billion funding request for the Strategic Defense Initiative was cut back to $3.9 billion.

Janice Long, Washington

Key protein absent in muscular dystrophy

Molecular biologists have found the biochemical defect responsible for the most common and deadly form of muscular dystrophy. The discovery of a protein that is missing from the muscles of victims may lead to better diagnosis, characterization, and eventually treatment of the disease.

Duchenne muscular dystrophy primarily affects boys, causing progressive weakness and wasting of muscle. Victims are usually confined to wheelchairs by age 12 and die from respiratory failure before reaching 30. Currently there is no treatment.

The key protein was isolated from normal human muscle tissue by a research team led by Louis M. Kunkel, associate investigator at Howard Hughes Medical Institute's Children's Hospital in Boston [*Cell*, **51,** 919 (1987)]. The protein, which the researchers named dystrophin, is completely absent from humans with Duchenne muscular dystrophy.

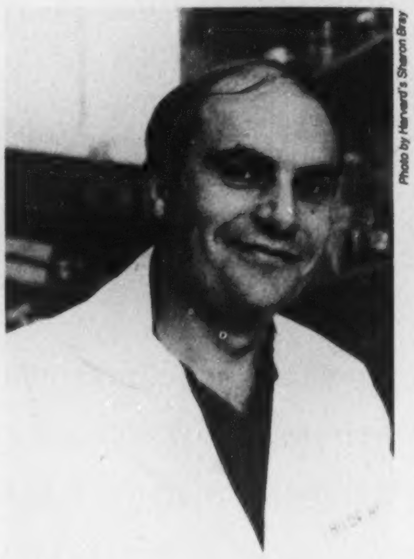


Photo by Harvard's Sharon Bray

Kunkel: led research on dystrophin

Kunkel and his coworkers from Harvard Medical School and the University of Iowa also located the site in normal muscle cells where dystrophin is found [*Nature,* **330,** 753 (1987)]. The same group previously reported that the gene that codes for dystrophin is located on the X-chromosome.

Dystrophin is a very large molecule (400,000 molecular weight) but it makes up only about 0.002% of total muscle protein. In normal individuals, dystrophin is found at triadic junctions, structures in muscle tissue where two membranes come together and information is passed from a nerve impulse to contractile muscle cells, according to Kunkel. "Possibly dystrophin serves as an anchor to hold the triadic structure in the appropriate place during contraction," he says. "Its absence might affect the normal process of transmitting signals."

Mice that have a genetic defect like Duchenne muscular dystrophy also are missing dystrophin from their muscle tissue. Kunkel points out, however, that such mice have much less muscle wasting and live normal lifespans. Discovering why the disease is so different in mice than in humans is one important research goal, Kunkel says. "The ultimate goal is to alter the course of the disease, to somehow replace the function of dystrophin," he says.

Pamela Zurer, Washington

A. H. Robins receives two new merger bids

No sooner had U.S. District Court Judge Robert R. Merhige in Richmond, Va., set A. H. Robins' liability to Dalkon Shield claimants at $2.475 billion than two suitors made new passes at the beleaguered pharmaceutical firm.

Robins already has a merger agreement worked out with the Rorer Group. However, Sanofi—France's second largest drug company—and American Home Products, which tried to buy Robins last February, both have made formal merger proposals to Robins. Other firms could also line up for takeover attempts of their own, now that the judge has essentially helped potential buyers establish Robins' value.

Judge Merhige, presiding over Robins' bankruptcy claim and financial reorganization plan, has given the company until this Wednesday to revise its plan and accept any one of the three merger proposals.

Lawyers for those claiming damages from use of Robins' Dalkon Shield intrauterine contraceptive device had suggested the judge set up a fund to settle claims that would contain $4 billion to $7 billion, but instead the judge set the $2.475 billion amount.

Paris-based Sanofi, 60% owned by the state oil firm Elf Aquitaine, has proposed to pay $500 million for a 60% stake in Robins. It also has promised to guarantee bank loans to fund the claimants' trust fund. Sanofi reported earnings of about $84 million in 1986 on sales of $2.1 billion.

American Home Products has proposed to swap $550 million of its own stock for Robins' shares. It also says it would provide cash over a maximum of seven years to fund the claimants' trust fund.

Last week, Rorer sweetened its offer for Robins. It agreed to pay Robins shareholders $482 million and added more than $700 million to its earlier offer of $1.75 billion for the compensation fund. Rorer is guaranteed a $25 million breakup fee if Robins accepts a competing bid.

Marc Reisch, New York

A1250-1
1/11/88

JANUARY 11, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR6602SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Congressional Outlook '88

Page 7

Volume 66, Number 2
CENEAR 66 (2) 1–50
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

JANUARY 11, 1988

News of the Week

- **Failure of latest solid rocket booster test firing means NASA will be forced to postpone shuttle flights, scheduled to resume June 2. Page 4**
- **Carl S. Marvel, one of the pioneers of synthetic polymer chemistry, died last week in Tucson, Ariz., at age 93. Page 5**
- **Swiss pharmaceuticals giant Hoffmann-La Roche launches an unfriendly $4.2 million takeover bid for Sterling Drug. Page 5**
- **Waste Management Inc. gives up on seeking EPA permission to burn hazardous wastes off the U.S. coast after six-year effort. Page 5**
- **Sites in eight states are chosen as finalists in race for Superconducting Super Collider. Page 6**
- **Testing of compounds to replace chlorofluorocarbons will intensify as 13 companies from around the world agree to more rigorous series of toxicity tests and pooling of information. Page 6**

Cover: Photo by Alan Kahan

Letters 2
Editor's Page 3

Concentrates

Business 12
Government 16
Science/Technology 19

The Departments

ACS News 27
Awards 31
Newscripts 50

Business

Ferro Corp.'s move to develop a research-business partnership is spurred by its new corporate research mission statement. **Page 14**

Science

Isotope separation process based on new chemical route may expand use of isotopes by lowering their production costs. **Page 20**

Stratospheric ozone has decreased globally, not just over Antarctica, according to a new analysis of satellite data. **Page 21**

Technology

Dermal exposure to dioxin in paper products is well below hazardous levels, says an American Paper Institute study. **Page 22**

Cycolor, a new cost-effective color reproduction technology developed by Mead Imaging, uses microcapsules called cyliths. **Page 23**

Books

Two books on 1984 lethal chemical leak in Bhopal, India, raise the level of insight on the tragedy. **Page 24**

News Focus

The second session of the 100th Congress will face a number of issues of importance to the chemical community, including biotechnology policy, use of alternative fuels in automobiles, reauthorization of pesticide and waste laws, AIDS testing, and product liability. Page 7

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Patricia Oates (Administrative Assistant)
News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 49)

LETTERS

National Chemistry Day

SIR: I am sure that stories will slowly be filtering in about things that occurred on National Chemistry Day that were a bit unusual. I could not resist passing this story along to you to share with fellow chemists.

About six years ago a lovely young couple, Angelina and Anthony, graduated from Pace University in New York, both having majored in chemistry. They married soon after graduation and they both went to graduate school at Rutgers University. Last year they both were awarded Ph.D. degrees in organic chemistry after working for the same research adviser. Now comes word that they have been blessed with their first child, Nicole Lucille, born Nov. 6, 1987, on National Chemistry Day. Since Tony is a real fan of chemacrostics (see back cover of *Chemtech*, September 1987), it did not escape our attention that the first two letters of the child's name represent the chemical symbols for nickel and lutetium.

John B. Sharkey
Chairman, Department of Chemistry and Physical Sciences
Pace University

Human visual range

SIR: Recently my attention was directed to an article entitled "The Chemistry of Vision" by Pamela S. Zurer (C&EN, Nov. 28, 1983, page 24). Although this was four years ago, I would like to comment favorably on the well-organized and clearly written article. The essence of my comments concerns the tremendous range in brightness the human visual system is capable of. In order to set the stage properly, allow me to quote the first paragraph. "The human sense of sight is exquisitely sensitive and adaptable. A person whose eyes have adjusted to darkness can sense the dimmest of light—less than 100 photons. Yet the same person needs only a minute to adjust to brilliant sunshine without being blinded. No man-made photographic system can function under such extremes." Then in the seventh paragraph I again quote, "Humans can see over a range of brightness covering six or seven powers of 10. Most of the process of adapting to changing light itensity occurs in the retina."

In the late 1950s, I invented a silver halide photographic film called XR for extended range for the express purpose of technical and scientific photography of nuclear explosions. Because the cameras used were of the remote automatic type, usually operated at high framing rates, it was not feasible to use mechanically adjustable exposures. Thus the film itself, disclosed in U.S. patent No. 3,450,536 and made by Eastman Kodak, had to contain the ability of recording over a tremendous brightness range of nine powers of 10 or a billion to one.

The inherent brightness range capability could easily have been increased by many more powers of 10. However, it seemed to be adequate for the intended purpose of recording a blinding flash exceeding that of the sun by a thousand times during one instant and then continuing to record a moment later the extremely low level recombination purplish light as faint as a luminous watch dial. (See *Life Magazine*, Dec. 23, 1966, page 112.) This special film was a so-called panchromatic black and white recording medium, whereas the remarkable human visual system produces a color sensation that is far more complex. However, using the principles involved in this film, I did invent a natural color film for the National Aeronautics & Space Administration and the Apollo moon landing program that had a response of six powers of 10 (see U.S. patents, No. 3,663,228; 3,812,507; and 3,849,138). This film has served as the model for Kodak's newer and much improved multi-multilayer color films.

Charles W. Wyckoff
Founder and Chairman of the Board
Brite-Line Corp., Boston

Benzene exposure

SIR: As reported in your article (C&EN, Sept. 7, 1987, page 7) and elsewhere, the Occupational Safety & Health Administration has finally recognized the inordinate risk of leukemia and other blood disorders due to benzene exposure in the workplace. A 90% reduction in workplace exposure, to 1 ppm over eight hours, has been ordered.

Although long-term workplace exposure is and continues to be a serious problem, research chemists should be alerted to the dire long-term consequences of even brief exposure to high levels of benzene (spillages, reaction runaways, etc.) by skin contact or inhalation.

The study by the National Institute for Occupational Safety & Health [*N. Engl. J. Med.*, **316**, 1044 (1987)] reported that rubber industry workers exposed to benzene vapors at levels of 10 ppm of air (the federal standard until September 1987) faced a threefold risk of leukemia

Continued on page 32

Federal 1989 budget proposal delayed

The Administration was supposed to submit its fiscal 1989 budget proposal to Congress on Jan. 5, but what Congress got instead was a letter from Office of Management & Budget director James C. Miller III saying that "I do not see any way to prepare a responsible budget proposal for transmittal before mid-February." The delay stems from Congress' not concluding final appropriation actions and reconciliation for fiscal 1988 until just before Christmas. Miller pointed out that OMB and the departments and agencies must now translate hundreds of pages of an omnibus continuing resolution and an omnibus budget conciliation bill into the precise detail necessary for a 1988 budget. That task has to be accomplished before the job of developing detailed information for a new set of fiscal 1989 budget proposals can be started.

Company convicted of environmental crimes

A Denver-based company, Protex Industries, has been convicted of violating federal laws by illegally endangering human life through the improper treatment and disposal of hazardous wastes. The Justice Department claims this is the first conviction ever under a law passed last year against endangerment of human life through treatment of wastes. The company was found guilty of three counts of knowing endangerment during the operation of a drum recycling operation. Fines can equal $1 million for each count. Three employees were exposed to residues of pesticides, including chlordane, and industrial solvents. Protex did not inform the workers of the hazards or train them or equip them to avoid exposures. The president of Protex still faces 11 charges of misconduct, including 10 counts of illegally storing or disposing of hazardous wastes. The investigation was conducted by EPA's National Enforcement Investigations Center and the Federal Bureau of Investigation.

Grapes still must be certified sulfite-low

Claiming there hasn't been enough time to consider all the alternatives, EPA has extended the year-old certification program for sulfites in grapes for another year. The current regulation, established in December 1986, requires that grapes imported or shipped in interstate commerce be certified to contain no detectable residues of sulfites (less than 10 ppm). Sulfiting agents (sulfur dioxide or sodium metabisulfite) used to prevent mold growth on grapes have been linked to allergic reaction in some consumers. FDA removed sulfites from its Generally Recognized As Safe designation in 1986, forcing EPA to reconsider its previous position of not needing a tolerance level. Grape producers have asked EPA to allow the continued use of low levels of sulfiting agents as long as the products are labeled as containing sulfites. EPA is considering this and other ideas.

Tougher standards for animal drug residues

Developers of new animal drugs will be required to establish analytical tests for detecting those drugs in animal tissue under new regulations proposed last week by FDA. The rule applies to any veterinary drug that is potentially carcinogenic. The test protocol must be sent to FDA with the drug's safety data and should be sufficiently sensitive to reveal a level of residue that would result in a maximum lifetime cancer risk of one in a million, FDA says. The previous standard for drug residues was a flat 2 ppb. In addition to the drug test, animal drug manufacturers must also present data on laboratory animal cancer testing, metabolic products in the animal, and where the residues remain in the body.

Use of CFC-22 allowed in food packaging

FDA has given Du Pont permission to market CFC-22 as a blowing agent for food packaging. Du Pont has developed new technology that allows CFC-22, which it calls Formacel-S, to be used in the production of plastic foams. Formacel-S replaces CFC-12, a vigorous depleter of stratospheric ozone. Because it is a hydrogen-containing compound, Formacel-S will reduce the potential for ozone depletion by 95% compared with CFC-12, Du Pont claims. The compound is less stable than CFC-12 and breaks down before reaching the stratosphere. It is not photochemically reactive or flammable, is low in toxicity and is chemically inert. FDA has allowed Du Pont to use Formacel-S in fast food containers. Du Pont is now seeking FDA's permission to use it in poultry and meat trays, and egg cartons. Formacel-S is more expensive than CFC-12, but lesser amounts of it are required to produce plastic foam packages.

Washington roundup

- Figures for the Department of Energy's R&D budgets were stated incorrectly in C&EN's article last week about the fiscal 1988 federal budget (Jan. 4, page 6). The total budget is up 6%, not 21%, to $4.9 billion. The energy R&D budget is up 6%, not 31%, to $3.4 billion; basic energy sciences is up 7%, not 20%, to $564.6 million; and weapons R&D and testing is up 7%, not 1%, to $1.5 billion.
- The Commerce Department is inviting suppliers of pollution control equipment to apply on a "first-come" basis for a trade mission to the Netherlands, West Germany, and Italy, May 15–25. For details, contact Jay Brandes, International Trade Administration, U.S. Department of Commerce, Room H2805, Washington, D.C. 20230, or phone (202) 377-0560.
- EPA has begun requiring that risk-reduction measures be added to the product label of the herbicide cyanazine as a condition for continued use and sale. The agency has determined that exposure may result in unreasonable risk to persons mixing, loading, and applying this chemical.

Low Health Risk Seen For Dioxin in Paper Products

Study finds skin exposure to TCDD in paper goods to be far below hazardous levels; work is under way on paper dust, food packaging

Last September, the Environmental Protection Agency and the paper industry announced that small amounts of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD) are present in pulp, wastewater, and sludge from paper mills. Of more pressing concern to the public, TCDD also appears in paper products to which consumers are exposed daily (C&EN, Oct. 5, 1987, page 19).

Not to worry, says the American Paper Institute. API has just released a study assessing potential health risks from dermal exposure to TCDD in paper products made from bleached pulp. The 130-page report finds that "any risk to consumers from normal use of products may be as low as zero and is considerably less than the one-in-a-million risk level used by the government to determine a virtually safe dose." The risk assessment, the only published review on the subject, was sponsored by the industry's environmental and research arm, the National Council of the Paper Industry for Air & Stream Improvement (NCASI), and was conducted by Envirologic Data Inc.

NCASI also is studying potential health threats from two other exposures: inhalation of paper dust, and ingestion of TCDD from food packaging and food contact products (such as coffee filters). In a few weeks, it will issue results of studies on TCDD in dust at workplaces doing much paper cutting.

As for food contact products, NCASI has released a preliminary report, finding no migration of TCDD out of packaging, and very low migration of a related but less potent furan—2,3,7,8-tetrachlorodibenzofuran (TCDF). However, the study must solve some basic analytical questions, such as finding suitable food-simulating liquids. The study will also collect the most extensive database available on paper products in contact with food.

TCDD and TCDF are formed as trace contaminants in paper mills during bleaching of kraft pulps with chlorine and chlorine derivatives to make white products. The bleaching process varies among mills, producing varying TCDD and TCDF levels. In a study of seven pulps, for example, TCDD levels ranged from nondetectable (below the detection limit of 1.0 ppt) to 51 ppt, with a median of 4.9 ppt. How TCDD and TCDF are formed chemically is not yet known, but studies are under way, notes Michael C. Farrar, API vice president for environmental and health affairs.

NCASI's assessment of the health risk from dermal exposure to TCDD defines "virtually safe" levels in various paper products, expressing them as the TCDD concentrations in bleached pulp yielding a lifetime cancer risk of one in a million. TCDD has been shown to cause cancer in animals, but a causal link for humans has not yet been established. Nevertheless, notes Dwain Winters, chief of the policy staff in EPA's office of toxic substances, his agency considers TCDD to be a "probable human carcinogen."

The NCASI study uses data on migration, transfer, absorption, and bioavailability of TCDD and its

Skin exposure to TCDD in paper products found negligible

	Safe level calculated TCDD,[a] ppt		Level measured TCDD, ppt
	Female	Male	
Bleached pulps			5[b]
Communication paper			13[c]
Clerical worker	9,000	9,100	
Manager	4,200	4,300	
Personal care products			
Disposable diapers			0[d]
Conventional	540,000	540,000	
Superabsorbent	2,000,000	2,000,000	
Facial tissue			
Normal use	66,000,000	79,000,000	
Makeup	230,000		
Toilet tissue	27,000,000	65,000,000	
Sanitary pads	63,000,000		
Paper towels	7,900,000	9,500,000	4
Composite personal care products[e]	160,000	510,000	
Combined communication papers-personal care products			
Clerical worker	8,500	8,900	
Manager	4,100	4,200	

a Virtually safe concentration of 2,3,7,8- tetrachlorodibenzo-p-dioxin (TCDD) equivalents in pulp, corresponding to a 1×10^{-6} cancer risk, at lower 95% statistical confidence bound. b Measured in seven pulps, with levels from not detectable (detection limit of 1.0 ppt) to 51 ppt, and a median of 4.9 ppt. c Measured in bond paper. d No TCDD detected in disposable diapers, at detection limits of 2.1 and 2.6 ppt. e Excluding superabsorbent disposable diapers. Source: National Council of the Paper Industry for Air & Stream Improvement equivalents from bleached pulp-based products to estimate what human uptake of TCDD would be from contact with skin. Models for each paper product enable calculation of potential exposure to TCDD over a working lifetime.

Calculations for communication papers (for writing, typing, books, and newspapers, excluding coated stock) show that levels ranging from 4200 ppt TCDD for female managers to 9100 ppt for male clerical workers would be considered virtually safe. For personal care products, safe levels range from 230,000 ppt for female use of facial tissues for makeup removal to 79 million ppt for normal use of facial tissue by males. Paper towels have safe levels of 7.9 million ppt for females, 9.5 million ppt for males.

By contrast, actual measurements find just 13 ppt of TCDD in bond paper, 4 ppt in paper towels, and no detectable level in disposable diapers (detection limits of 2.1 and 2.6 ppt). Thus, actual TCDD levels are orders of magnitude less than the concentrations estimated to be safe.

The paper industry's studies so far on TCDD in paper are "commendable," says Ellen K. Silbergeld, a toxicologist with the Environmental Defense Fund. However, she notes, there are so many other exposures that a more general approach should be taken, going after the upper and lower risk limits. She urges an upper limit of 10 ppt TCDD in paper for food-related uses.

EPA, for its part, will be evaluating the report on dermal exposure—and looking at partition coefficients or migration potential from paper products to humans—to determine whether there is a risk to be regulated. EPA leads an interagency group that includes the Food & Drug Administration and the Consumer Product Safety Commission, Winters notes. EPA also will survey the more than 100 U.S. paper mills for TCDD in pulp, wastewater, and sludge. If there is a hazard in disposal of wastewater or sludge, or in use of paper products, it would be best handled by changing the bleaching process to eliminate TCDD formation, he stresses.

Richard Seltzer, Washington

New color technology uses microcapsules

Mead Imaging has high hopes for a new color reproduction technology it has developed and calls Cycolor. Mead Imaging president Charles W. Joiner Jr. says that the technology is simple and cost-effective enough that color reproduction need no longer be an expensive luxury. "Instead," he says, "color can become the standard for all business communications."

Cycolor is a color, photographic-like, film technology. No silver halide is used, and the film is sensitive to visible light.

Calling Cycolor a major breakthrough in color-imaging technology, Joiner says that it will make possible the development of office equipment that would bring the graphic impact of color to everyday business communications. Using the new process, he explains, companies would be able to make the use of color hard copy and overhead transparencies standard business practice.

That, at least, is Mead Imaging's hope. The company was formed in 1984 as a division of Mead Corp., a forest products and electronic publishing company headquartered in Dayton, Ohio. Its mission was to develop and commercialize a new color-imaging technology based on light-sensitive microcapsules.

The resulting technology makes use of a film coated with such microcapsules, called cyliths, that are on the order of 5 μm in diameter. These are sensitive to red, green, and blue light, so that, when the film is exposed to light, a latent image is produced. The latent image is a pattern made up of exposed and nonexposed cyliths.

Each cylith contains a liquid monomer. Dissolved in the monomer is a light-sensitive photoinitiator and a color-forming substance called a leuco dye, which is colorless until it reacts. Exposure of the film to light causes the cyliths to harden in proportion to the amount of exposure, making them resistant to rupture. The latent image is thus formed by hard (exposed) and soft (not exposed) cyliths.

For development, the Cycolor film and Cycolor paper or transparency material are compressed together through a set of pressure rollers. Unexposed cyliths release dyes to the paper or transparency, and the dyes react with the coating on either to produce a color image. In a final step, the paper or transparency is heated briefly to enhance the quality of the color reproduction.

Full color is achieved through use of a mixture of three different types of cyliths coated on the film in a single layer. The three contain either cyan, magenta, or yellow leuco dyes, along with the photoinitiators, which are sensitive to red, green, or blue light, respectively. Exposure to red light, for example, hardens the capsules containing cyan dye, and pressure on the cylith capsules causes the release of magenta and yellow dyes, which mix to form a red image. Likewise, exposure to green light controls the magenta dye, with development resulting in cyan and yellow dyes mixing to form a green image. In a similar manner, blue light controls the yellow dye. Exposure of all cyliths (white light) results in no color (white), and exposure of none of the cyliths results in black. Any color can be reproduced, Mead Imaging explains, by controlling the relative proportion of the three dyes.

Mead Imaging sees a number of markets for the Cycolor technology and is working with other firms that are developing the hardware to employ it. One use, for example, is in color copiers. Another is in 35-mm slide printers, providing a simple and inexpensive way to create hard copy prints from 35-mm slides used in business presentations. A third use is in color computer printers, which would have desktop publishing, scientific, technical, and general business applications. Also, Mead Imaging points out, Cycolor technology works effectively with a variety of digital imaging techniques. For example, it meets the need, the company says, for high-quality, low-cost hard copies of images produced by electronic cameras.

James Krieger, Washington

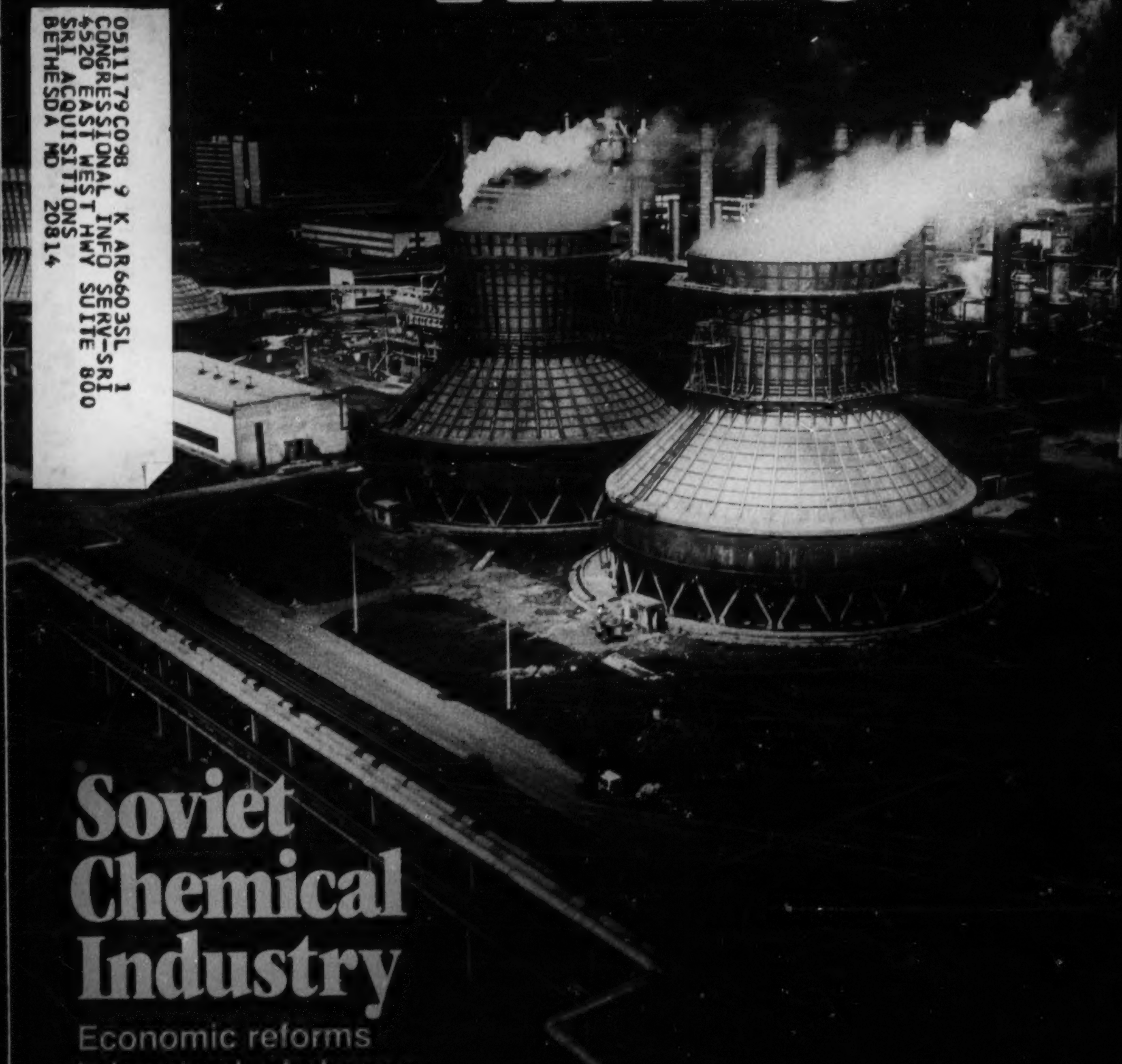
A1250-1
1/88

Chemical companies' R&D spending to increase this year
Page 9

JANUARY 18, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR6603SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814



Soviet Chemical Industry

Economic reforms bring gradual change
Page 28

CHEMICAL & ENGINEERING
NEWS
JANUARY 18, 1988

Volume 66, Number 3
CENEAR 66 (3) 1–68
ISSN 0009-2347

News of the Week

- **Reagan-Takeshita meeting opens negotiations for U.S.-Japanese scientific exchange, but policy differences jam process.** **Page 4**
- **Lawsuit by Sterling Drug Co. impelled by Hoffmann-La Roche's hostile takeover attempt emphasizes differences in U.S. and Swiss accounting practices.** **Page 5**
- **Du Pont's celebration of nylon and Teflon's 50th anniversary pays tribute to materials revolution, looks to future developments.** **Page 5**
- **In acerbic response to U.S. acid rain report, Canada's environment minister calls it flawed, incomplete, and misleading.** **Page 6**
- **Chicago judge rules Amoco must pay $85 million to French plaintiffs for 1978 wreck of its supertanker, but appeals are certain.** **Page 6**

Business

Major chemical producers' R&D spending will increase modestly in 1988, following similar increase in 1987. **Page 9**

Government

Petrochemical companies meet IRS head-on to resolve problems in dealing with excise tax on gasoline blend stocks. **Page 15**

Fiscal 1988 budget gives meager 4% increase to federal R&D funding, with NIH and NSF receiving greater percentage increases than Department of Defense. **Page 16**

Science

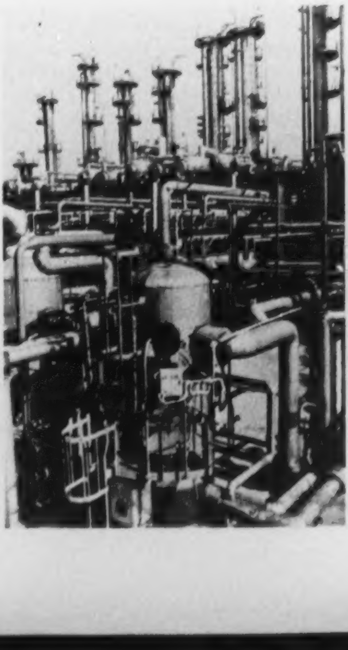
New estimates for cancer risk from radon exposure are set by National Research Council study. **Page 22**

High-temperature superconductors are used to make an electrical motor at Argonne National Laboratory. **Page 23**

First examples of simple metal carbonyls of zirconium and titanium are synthesized by University of Minnesota chemists. **Page 23**

Technology

High-yield, direct methane conversion to chemicals by a transition metal compound in homogeneous solution is achieved. **Page 27**



Cover: Nizhnekamsk petrochemical complex, near Kazan, a leading producer of synthetic rubber and commodity petrochemicals; it has recently been involved with a joint venture in instrumentation with Combustion Engineering. Photo by Tass from Sovfoto

Special Report

In U.S.S.R., influx of new Gorbachev-backed ministers to industrial posts bodes well for economic and social reforms in the chemical industry. **Page 28**

Letters 2

Concentrates

Business 7
Government 14
Science/Technology 21

The Departments

ACS News 55
Newscripts 68

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Patricia Oates (Administrative Assistant)
News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified, if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 67)

LETTERS

ACS activities

SIR: There is a simple answer to J. J. Doheny's plea (C&EN, Nov. 23, 1987, page 2) for ACS governance to draw a line in determining what activities are suitable for the society to sponsor. (Those he questions include selling jewelry in our exhibit areas, sponsoring concerts, introducing a lonely hearts page in C&EN and others.)

The simple way to determine the suitability of any candidate ACS activity is to test whether it contributes to the survival of the society. That is, to determine whether or not it earns at least as much money as it costs. Soon enough the members will tell us with their pocketbooks how strongly they approve of an activity. And I, for one, prefer the law of the marketplace—every time—to an arbitrary ruling by those who think they represent some silent majority. In short, we don't need to address the three criteria laid down by the Membership Affairs Committee, but only one: "Will it pay?"

B. J. Luberoff
Summit, N.J.

Agent orange exposure

SIR: This is in regard to your article, "Science Failing To Back Up Veteran Concerns About Agent Orange" (C&EN, Nov. 9, 1987, page 7). We believe some aspects of this article deserve comment.

To begin, there seems to be a strong sense in this article that science has done all it can do to investigate the effect of exposure on Vietnam veterans and has reached a stalemate, with very little tangible results. The tenor here seems to be frustration and a strong urge to throw in the towel on this issue. We believe that there remains significant research yet to be done and that the real work is only beginning.

Progress is being made, although it is slow and sometimes very frustrating. You inadvertently point this out in the article when you say that "no one denies" that those who handled agent orange regularly are likely to have elevated levels of 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). The fact is that just a few years ago that was precisely the denial in many circles, until science proved that such levels could be found.

We believe there may be better exposure models to test veterans than the "hit" model used by the Centers for Disease Control. We believe it is possible to identify exposed veterans by using a combination of military records and other sources. Our current research, "Pointman II," focuses on an environmental model that will look at a particular group of infantry personnel from the Second Battalion, Eighth Cavalry. We have identified with good precision their activities in the Third Corps area of Vietnam. This unit worked extensively in defoliated areas north of Tay Ninh in 1969. At this point we do not know what levels of TCDD we may find in these veterans, but it is vitally important to continue to investigate specifically identified groups in order to potentially identify those who may have been heavily exposed.

Perhaps certain elements of the federal government want to walk away from Vietnam veterans, but we feel it is immoral to do so. New and creative approaches to this research are needed, and we support such concepts as federally funded investigator-initiated projects. This would allow those with a desire to pursue this research to do so, probably at far lower overall cost than CDC-type efforts.

We don't know what effect agent orange may have on Vietnam veterans, but until we've exhausted all reasonable investigations, we have not tried hard enough to find the answer.

William W. Lewis
Project Coordinator
New Jersey Agent Orange Commission
Trenton, N.J.

Hazardous waste

SIR: This is in regards to the article on hazardous waste in household garbage (C&EN, Oct. 12, 1987, page 14). Although the study is interesting, some of the substances comprising those so-called hazardous products are ending up highly diluted. What is important is to watch that nothing other than household garbage is disposed of in any unregulated dumpsite.

To call alcohol, acetone, and a diversity of esters "hazardous" is improper, because they are produced in much larger quantities by natural fermentation processes of the same garbage components.

If household maintenance residues are the largest source of hazardous products, then we may have to live with them. It would be impractical if all households would be required to set up several cans for each of the individual types of waste. Then where would they go?

However, if the concern is waste in general because we are running out of space, then there are the studies of Elec-

Chemical Industry R&D Spending To Rise Modestly in 1988

Major chemical producers plan 6% hike in research expenditures this year, translating to only about 1.5% in constant-dollar terms

Marc S. Reisch, C&EN New York

The U.S. chemical industry projects only a modest increase in its research and development spending in 1988, according to C&EN's annual survey of large chemical producers.

The survey indicates that R&D spending for 11 companies will increase 6% this year, following a similar increase in 1987. (Du Pont, which is usually included in the C&EN survey, declined to estimate 1987 spending or to forecast 1988 expenditures.) The 6% increase in planned R&D expenditures determined by C&EN's survey is only marginally lower than the 6.9% increase in R&D spending for all industry forecast by Battelle Columbus Laboratories for 1988.

But the chemical industry's 6% increase means that, adjusted for inflation, chemical R&D spending will be up only 1.5% in 1988. This constant-dollar increase is figured using Battelle's estimate for 1988 R&D inflation of about 4.5%.

If Du Pont's 1988 R&D spending increase turns out to be modest, constant-dollar spending could show a marginal decrease. Du Pont traditionally spends more on R&D than any of the other 11 companies included in this survey. In 1986, for instance, Du Pont spent $1.07 billion, or almost 32% of the total R&D expenditures of the group.

The modest increase in constant-dollar R&D spending can be attributed in part to the mergers, acquisitions, and company restructurings that have taken place within the industry over the past few years. Myron Foveaux, trade and economic policy adviser to the Chemical Manufacturers Association, notes that many R&D facilities have been merged during the past five years and that fewer people are now engaged in research activities as a result. He expresses concern that recent increases in R&D spending are falling below the average annual rate of increase of 12.7% for the decade 1977 to 1987. "Spending for R&D for new products traditionally has been the engine of growth for the chemical industry," he notes.

R&D spending as a percentage of sales has decreased marginally in 1987 to 5.0%, compared with 5.4% the year before. Part of the reason may be that sales growth has been better for the chemical industry in 1987 than had been anticipated when 1987 R&D spending plans were put into place. Based on spending plans of the 11 companies in the survey, 1988 R&D spending as a percentage of sales will probably remain about the same as in 1987.

The biggest increase in R&D spending for 1988 is planned by Air Products & Chemicals, whose spending is slated to rise 17.5% to $67 million as the company targets research to increase the purity of gases for the electronics industry. Other increases in the company's R&D are planned for urethane additives and noncryogenic gas separations. Air Products' planned increase for 1988 follows a 6.6% decline in R&D spending last year—a decline greater than the 3.3% decrease originally planned for 1987.

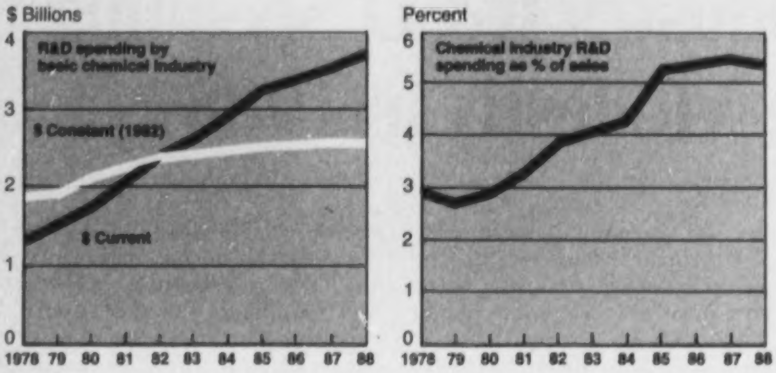
The second largest R&D increase in 1988 is planned by American Cyanamid, which expects to increase R&D funding 13% to $356 million in 1988. That increase follows a similar rise the year before, when Cyanamid says it spent the $315 million it originally planned to spend.

Union Carbide also plans an above-average increase in R&D spending for 1988: 9.4% to $175 million. That increase follows an 8.1% increase the year before. R&D spending as a percentage of sales has remained constant at 2.4% in both 1986 and 1987 for Carbide.

W. R. Grace plans to spend $120 million on R&D in 1988, up 9.1% from the previous year. The increase in its R&D effort is decelerating compared with what the company says it spent in 1987. In 1987 Grace spent $110 million on R&D, up 17% from the $94 million spent in 1986.

Rohm & Haas predicts a more modest 7.1% increase in its R&D

Air Products scientist studies gas purification at lab in Allentown, Pa.



R&D spending will level off in 1988 . . .

. . . and will slip as percent of company sales

Note: For companies listed on page 13. **Sources:** C&EN surveys and estimates, Battelle Columbus Laboratories

budget, increasing to $150 million. That increase is better than the 5.3% increase in 1987 to $140 million.

Dow Chemical plans to increase spending dramatically less in 1988, with R&D spending rising only 6.7% to $720 million, compared with an 11.6% increase in 1987 to $675 million. The company's R&D spending as a percentage of sales, at 5.8% in 1987, is the fourth highest in the survey after American Cyanamid, Monsanto, and Rohm & Haas.

Hercules plans to increase its R&D effort in 1988 some 5.6%, an improvement over its 1.4% increase in 1987. However, it did transfer its water-soluble polymers business to a joint venture with Henkel in 1987, and thus the R&D figures for that business are not included in the 1987 numbers. For 1988, Hercules comes in a tad under the average increase in R&D budget growth determined in this survey.

Six companies mentioned so far are planning R&D budget increases above the average for the 11 that responded to the survey, and one, Hercules, is just under the average. An additional company is planning an increase of about 1% and three others are planning no increase at all. Given the 4.5% increase necessary just to stay even in constant-dollar spending, four companies actually plan a decline in constant-dollar spending: Monsanto, PPG Industries, Olin, and Ethyl.

Monsanto plans a very modest 0.9% increase in 1988 to $538 mil-

In a merger of strengths

Some Things Change. . . .

Hoechst Celanese
Chemical Group

Hoechst Celanese

Hoechst

R&D spending as percent of future-oriented expenditures stabilized in 1987

R&D expenditures as a percentage of future-oriented spending (capital expenditures plus R&D expenditures) has been fairly stable over the past two years for the 12 major chemical producers C&EN contacted for its annual survey. In 1987 the R&D portion accounted for 38.3% of a total $9.32 billion in future-oriented spending, and in 1986 it accounted for 38.4% of a total $8.76 billion.

The relationship has been preserved because R&D spending and capital spending for the 12 companies grew at about the same 6% rate in 1987. In its recent survey of chemical capital spending, C&EN reported that capital spending by the same 12 major chemical companies rose 6% in 1987 to $5.75 billion (C&EN, Dec. 21, 1987, page 10).

The relationship between the two spending figures has changed dramatically since 1980, a year when capital expenditures for the 12 companies were at $6.66 billion, or 78.8% of a total $8.45 billion in future-oriented spending, and R&D expenditures were 21.2%.

However, by 1983 the relationship had changed drastically. R&D spending amounted to 34.8% of the total $7.50 billion directed at future-oriented spending. The R&D figure rose steadily to 36.5% of future-oriented spending in 1985 and hit its highest point in 1986, when 38.4%, or $3.36 billion, went to R&D efforts for the 12 companies in the survey.

lion. That's a far cry from last year, when the company's R&D budget fell 10.6% to $533 million. Although Monsanto added the expanded research programs of its Searle subsidiary to its budget in 1986, it has subsequently trimmed its R&D levels, bringing R&D spending as a percentage of sales down from 8.7% in 1986 to 7.4% in 1987. Monsanto, however, generally spends more on R&D as a percentage of sales than any other company in the survey, the industry averages for which were 5.4% in 1986 and 5.0% in 1987.

Among diversified manufacturers, which C&EN has included in its survey for the first time this year, four companies plan to increase their R&D budgets 4% in 1988. They are Allied-Signal, Eli Lilly, FMC, and Morton Thiokol. Their figures include internally generated R&D only and not government contracts. Morton Thiokol's 1988 planned government-sponsored R&D at $250 million, for instance, dwarfs the

And Some Things Don't.

On January 1, 1988, Celanese Chemical Company, Inc. becomes Hoechst Celanese Chemical Group.

CIRCLE 12 ON READER SERVICE CARD

Air Products, American Cyanamid will post biggest gains in R&D spending

$ Millions	Planned 1988	Actual 1987	Planned 1987	1986	1985	1984	1983	1982	Change from previous year		R&D spending as % of sales	
									1988	1987	1987	1986
CHEMICAL COMPANIES												
Air Products[a]	$ 67	$ 57	$ 59	$ 61	$ 51	$ 44	$ 40	$ 37	17.5%	−6.6%	2.7%	3.1%
American Cyanamid	356	315	315	278	251	232	208	185	13.0	13.3	7.9	7.3
Dow Chemical	720	675	650	605	547	507	492	460	6.7	11.6	5.8	5.4
Du Pont[b]	na	na	1110	1070	1080	1000	875	775	na	na	na	6.8
Ethyl	52	52	47	47	47	40	39	39	0	10.6	3.1	2.9
W. R. Grace	120	110	110	94	92	81	73	64	9.1	17.0	2.8	2.5
Hercules	76	72	68	71	76	72	74	74	5.6	1.4	2.6	2.7
Monsanto	538	533	575	596	470	370	290	264	0.9	−10.6	7.4	8.7
Olin	60	60	60	56	53	52	49	45	0	7.1	3.3	3.3
PPG Industries	250	250	na	204	176	150	127	127	0	22.5	5.1	4.4
Rohm & Haas	150	140	133	133	124	109	100	92	7.1	5.3	6.5	6.4
Union Carbide	175	160	na	148	275	265	245	240	9.4	8.1	2.4	2.4
TOTAL	**$2564**	**$2424**	**$3127**	**$3363**	**$3242**	**$2922**	**$2612**	**$2402**			**5.0%**	**5.4%**
ANNUAL CHANGE[c]	**6%**	**6%**		**4%**	**11%**	**12%**	**9%**	**15%**				
DIVERSIFIED COMPANIES												
Allied-Signal[d]	670	670		462	343	258	245	166	0	45.0	5.4	3.9
Arco Chemical	na	na		30	29	29	na		na	na	na	1.9
Eli Lilly	500	450		427	370	341	294	267	11.1	5.4	11.5	11.5
FMC	134	134		146	149	121	102	105	0	−8.2	4.2	4.9
Merck & Co.	na	530		480	426	393	356	320	na	10.4	12.2	11.6
Morton Thiokol[d,e]	43	40		38	34	28	21	7	7.5	5.3	2.0	1.9
SmithKline Beckman	na	425		377	310	279	265	222	na	12.7	11.3	11.6
TOTAL	**$1347**	**$2249**		**$1960**	**$1661**	**$1449**	**$1263**	**$1087**			**7.2%**	**6.7%**
ANNUAL CHANGE[c]	**4%**	**17%**		**18%**	**15%**	**11%**	**16%**	**14%**				

a For fiscal year ended Sept. 30. b All figures exclude Conoco. c For those companies reporting. d Includes all company-financed R&D, but excludes contract R&D. e Fiscal year ended June 30. na = not available.

money the company spends on its chemical and salt operations. Allied-Signal's government and other contract R&D spending, at $530 million, is almost as large as the $670 million Allied spends on internal R&D.

Among the pharmaceutical manufacturers included for the first time, only Eli Lilly could provide an estimate of what it planned to spend in 1988. Its $500 million in R&D expenditures planned in 1988 is 11.1% higher than in 1987, and its 1987 R&D expenditures were 5.4% ahead of 1986. Merck and SmithKline Beckman reported that they had spent $530 million and $425 million, respectively, in 1987, marking 10.4% and 12.7% increases in R&D spending over 1986.

The Pharmaceutical Manufacturers Association (PMA), an organization representing more than 100 research-based pharmaceutical companies in the U.S., recently reported a survey indicating that the industry increased its R&D spending 14.9% in 1987 and 14.6% in 1986. Eli Lilly, Merck, and SmithKline fall below the industry level of increase, according to C&EN's survey.

PMA also estimates the industry level of R&D spending as a percentage of sales at 15.1% in 1987 and 14.8% in 1986. Again, the companies surveyed by C&EN came in under the industry level. Eli Lilly spent 11.5% of its sales on R&D in both 1986 and 1987, and Merck spent 11.6% and 12.2% in 1986 and 1987, respectively. SmithKline spent 11.3% of sales on R&D in 1987 and 11.6% in 1986.

As a group, however, the three pharmaceutical companies consistently spent more on R&D than other diversified companies surveyed and are in large measure responsible for the year-to-year increases shown in the group.

Although Allied-Signal's $670 million spending plans show no growth in its R&D budget for 1988, the company did show a rather hefty increase of 45% the year before, when R&D spending as a percentage of sales increased dramatically to 5.4% from 3.9% in 1986.

Arco Chemical, spun off from Atlantic Richfield late last year, is included in the diversified table as well. Historical data from its prospectus show a rather consistent level of R&D by this manufacturer of commodity chemicals (such as propylene oxide, styrene, and oxygenated fuels).

FMC reported no plans to increase its R&D expenditures above its 1987 level of $134 million. Its 1987 spending was 8.2% less than in 1986. As a percentage of sales, R&D spending stood at 4.2% in 1987 and 4.9% in 1986.

Morton Thiokol plans a modest 7.5% increase in internally generated R&D this year to $43 million, following a 5.3% increase in 1987. Its R&D spending as a percentage of sales remained fairly constant at 2.0% in 1987 and 1.9% in 1986. □

petrochemical products are taxable and some are not when delivered to the same customer in the same tank.

A number of comments focused on administration of the tax. Under the proposal, any transfer or sale of taxable products is taxed. Thus, a chemical producer would have to pay the tax on a shipment of toluene, for example, whether or not it ever ended up in gasoline. However, if the material is not used as a motor fuel, a refund can be applied for. It is even unclear whether or not the tax applies to transfers inside a company facility.

If the exemptions are not allowed (and some say even if they are), a heavy paperwork burden is likely to result. A representative of chemical distributors estimated that at least 30,000 chemical distributors would have to pay the taxes and then file for a refund each quarter. In its comments, Hoechst-Celanese Corp. told IRS these "provisions for the gasoline excise tax will be market damaging and extremely expensive to the entire petrochemical industry."

IRS did provide exemptions for transfers and shipments in bulk. But it defines bulk transfers as quantities of more than 10,000 barrels. Such a quantity could be moved without an upfront payment of the excise tax. Unfortunately, very few shipments are this large. Even when moved on barges or in pipelines, individual loads are smaller than that size limit. There are some safety restrictions that keep shipments below 10,000 bbl even if the barge can hold more. Several industry sources pointed out that in the petrochemicals business, it's not the size of the load that is termed bulk, but the mode of transfer, such as by pipeline. Chemical industry speakers recommended the limit for bulk shipments be put at 15,000 gal, about the size of a railroad tank car.

The bonding requirement was seen as severe by many commenters, and as potentially disastrous for many smaller shippers. Most speakers told IRS that a company that is in good financial condition and has paid its taxes promptly in the past should be exempted from the bonding requirement. It was pointed out that tax cheaters in the past had not held proper tax registration credentials and that refiners should not be punished unnecessarily. One speaker noted that the law gives IRS some discretion in requiring bonding and that the bond requirement was not intended by Congress for faithful taxpayers. How IRS will resolve this is unclear.

No one was objecting to paying the excise tax but many held that this method of collection would not lead to a great increase in revenue. It will generate a tremendous clutter of payments and refund requests that will be burdensome not only to the companies involved, but to IRS as well.

David Hanson, Washington

Federal R&D funding up marginally in 1988

Federal R&D support totals more than $55 billion and accounts for about 9% of discretionary spending in the fiscal 1988 budget, according to the continuing appropriations bill, H.J. Res. 395, approved by Congress late last year. That total represents a 4% increase over fiscal 1987 funding levels, barely enough to keep up with inflation.

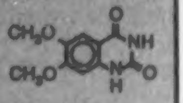
H.J. Res. 395 is a massive document, printed on more than 2300 pages. It not only sets budget dollar amounts, but in many cases directs where and how the money is to be spent and on what. Examples can be found in just about every R&D budget, from the largest to the smallest.

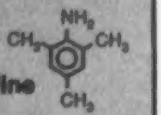
The largest, of course, belongs to the Department of Defense, but DOD receives one of the smallest percentage increases in fiscal 1988. Its research, development, test, and evaluation (RDT&E) programs budget rises 2% to $37 billion. However, DOD's technology base budget, which funds basic research programs, is essentially unchanged at $3.2 billion. Within that budget category, funding for DOD's University Research Initiative (URI) is also unchanged at $110 million, with $85 million earmarked for research and $25 million for instrumentation grants. The conferees decided that

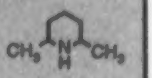
ORGANIC
INTERMEDIATES
FROM SWITZERLAND

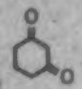
for
- pharmaceuticals
- agrochemicals
- dyestuffs
- flavors
- fragrances
- photochemicals

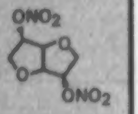
1-Ethoxycarbonylpiperazine

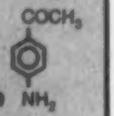

6,7-Dimethoxy-quinazoline-2,4-dione


2,4,6-Trimethylaniline
Mesidine


2,6-Dimethylpiperidine, cis


1,3-Cyclohexanedione


Isosorbide dinitrate (ISDN)
mixtures with lactose etc., USP XXI


4-Aminoacetophenone

US-Agents:
HENLEY CHEMICALS, INC.
50, Chestnut Ridge Road
Montvale, NJ 07646
Phone (201) 307-0422

SSF DOTTIKON

CH-5605 Dottikon/Switzerland
Phone 057/26 11 55
Telex 827 923 ssf ch

CIRCLE 22 ON READER SERVICE CARD

"not more than 14% of funds made available in this act for the URI program may be obligated or expended within any one state." That marks the first time Congress has imposed a geographic cap on research funds. Congress also earmarked $135 million of the RDT&E budget for various semiconductor research programs and allotted $15 million for research on high-temperature superconductivity.

Funding for the National Institutes of Health is up 11%, or $733 million, over fiscal 1987, to $6.7 billion. Much of that increase is earmarked for acquired immune deficiency syndrome (AIDS) research by various institutes, which is up 77%, or $196 million, to $448 million. That leaves a 5% increase for NIH's non-AIDS research. House and Senate conferees on H.J. Res. 395 agreed that NIH should fund "approximately 6100 new and competing research project grants, including those related to AIDS."

For the Department of Energy,

Funding for major R&D agencies is up less than $2 billion

$ Millions	1988 Final appropriation	1988 Administration request	1987	% change 1987–88
DEFENSE	**$36,814.9**	**$43,436.3**	**$36,121.1**	**2%**
Tactical programs	12,230.6	13,726.5	11,038.6	11
Strategic programs	7,406.3	9,989.9	8,124.7	−9
Advanced technology development	5,357.2	7,163.2	4,930.2	9
Intelligence and communication	4,873.1	5,262.1	4,882.5	0
Defensewide mission support	3,655.5	3,874.0	3,911.9	−7
Technology base	3,247.5	3,420.6	3,233.2	0
Conventional defense initiative	83.2			
Reduction	−38.5			
NIH	**6,666.6**	**5,190.5**	**5,933.5**	**11**
Cancer	1,469.3	1,217.9	1,341.8	10
Heart, Lung & Blood	965.5	801.1	913.3	6
Allergy & Infectious Diseases	638.8	349.4	400.0	60
General Medical Sciences	632.7	482.0	571.2	11
Diabetes, Digestive & Kidney Diseases	534.7	440.3	511.4	5
Neurological & Communicative Disorders & Stroke	534.7	420.3	488.1	9
Child Health & Human Development	396.8	312.6	362.8	9
Research Resources	368.2	254.7	315.1	17
Eye	224.9	184.6	216.5	4
Environmental Health Science	215.7	196.9	209.2	3
Aging	194.7	155.8	177.5	10
Arthritis & Musculoskeletal & Skin Diseases	147.7	123.0	138.8	11
Dental Research	126.3	105.3	115.3	9
Other	216.6	146.4	172.5	26

Note: All figures are estimates. Source: Congressional budget documents

Everything.

*Trademark of The Dow Chemical Company

$ Millions	1988 Final appropriation	1988 Administration request	1987	% change 1987–88
ENERGY	$4,863.1	$4,446.7	$4,578.3	6%
Energy supply R&D	2,108.4	1,925.8	2,024.0	4
Supporting research & technical analysis	648.5	561.0	607.4	7
Nuclear	603.8	590.7	610.8	−1
Fusion	335.0	345.6	345.3	−3
Biological & environmental	265.2	217.5	194.0	37
Other	255.9	211.0	266.5	−4
Weapons R&D, testing	1,466.9	1,476.4	1,377.2	7
General science & research	804.5	814.5	719.5	12
Fossil R&D	327.0	149.9	295.9	10
Conservation R&D	156.3	80.1	161.7	−3
NASA R&D	3,274.2	3,651.2	3,127.7	5
NSF	1,717.0	1,892.5	1,622.2	6
Research & related activities	1,453.0	1,634.5	1,406.2	3
Science education	139.2	115.0	99.0	41
Antarctic program	124.8	143.0	117.0	7
COMMERCE	1,254.8	1,151.9	1,168.0	7
NOAA	1,110.0	1,013.3	1,044.6	6
NBS	144.8	138.6	123.4	17
USDA	979.9	897.6	953.0	3
Agricultural Research Service	540.7	535.1	514.2	5
Cooperative State Research Service	303.7	240.3	304.1	0
Forest research	135.5	122.2	132.7	2
EPA R&D	186.4	187.6	202.5	−8
TOTAL	$55,756.9	$60,854.3	$53,706.3	4%

whose overall R&D budget rises 6% to $4.8 billion, funding for chemical sciences is up 13%, or $15 million, to $131 million. Included in the increase is $6.5 million for refurbishing the high-flux isotope reactor at Oak Ridge, Tenn., and "$3.5 million to fund a new initiative in fundamental chemistry as identified by the NAS/NRC Committee to Survey the Chemical Sciences," the group responsible for "Opportunities in Chemistry" (the Pimentel Report). The materials science budget increases 11%, or $17 million, to $172 million. It provides $10 million to initiate a technology program in x-ray lithography, $4 million for creation of a national research program in ceramic superconducting technology, and up to $3.5 million for development of expanded projects and programs in materials processing. And the conferees agreed to provide $25 million out of the $804 million general science and research budget for Superconducting Super Collider

From head to tow.

Dow polyglycols perform. As everything from solubilizers in facial creams to lubricants for transport chains. And beyond. Dow's unique alkoxylation capabilities give you the freedom to create new applications with custom ethylene oxide, propylene oxide, and butylene oxide derivatives. For an almost unlimited range of product possibilities. And now, everything you've always wanted to know about polyglycols has been condensed into one invaluable technical resource. The Dow Polyglycol Handbook. And a copy is yours when you call 1-800-258-CHEM. Or circle the reader service number below.

DOW
Polyglycols
The possibilities are endless.

CIRCLE 9 ON READER SERVICE CARD

The Polyglycol Handbook

The TGA/FT-IR System.

The World's first *fully* integrated TGA/FT-IR system.

Our *new* TGA/FT-IR is the first (and only) to combine a research grade thermogravimetric instrument and the world's most sensitive FT-IR spectrometer into a physically integrated system controlled from a single data system. For those studying the thermal decomposition and combustion of plastics, textiles, paper, fuels, minerals, propellants, catalysts and other materials, that means TGA/FT-IR with remarkable sensitivity, ease-of-use and economy. For more details, call (617)868-4330, ext 150. Or write Bio-Rad Digilab Division, 237 Putnam Ave., Cambridge, MA 02139.

BIO-RAD Digilab Division

CIRCLE 5 ON READER SERVICE CARD

3-Bromopropionic Acid

$BrCH_2CH_2CO_2H$

Please Contact: AUSTIN

Austin Chemical Company, Inc.
8410 West Bryn Mawr Ave., Chicago, IL 60631
(312) 399-0490, Telex 280342, Telefax (312) 399-1138

CIRCLE 33 ON READER SERVICE CARD

R&D. No funds were provided for initiating construction.

On paper the National Aeronautics & Space Administration's budget is up 5%, or $146 million, to $3.3 billion. However, the conferees agreed to Senate language allowing $100 million of 1987 funding for a replacement shuttle to be transferred to the 1988 R&D account, for an 8% increase. Requested funding for the space station was cut $343 million, to $425 million. The conferees noted that it is imperative that NASA examine all possible approaches to constraining station costs so that it can maintain activities such as science research at not less than 20% of its total resources.

The National Science Foundation, which up until the last minute had reason to hope that it would get a good part of the 16% increase requested for its research and related activities budget, instead gets only a 3% increase to $1.5 billion. The Department of Commerce's National Oceanic & Atmospheric Administration's operations, research, and facilities budget increases 6% to $1.1 billion, but the National Bureau of Standards budget rises 17% to $145 million. The NBS budget includes $2.8 million for superconductivity, $1.5 million for composites, and $950,000 for cleanup of polychlorinated biphenyls.

Overall, research funding for the Department of Agriculture is up 3% to $980 million. However, funding for the Cooperative State Research Services shows no increase at $304 million, even though the conferees rejected the Administration's proposal to abolish the special research grants program, funded at $31 million, which is aimed at specific problems such as the blueberry shoestring virus.

For the Department of Interior, research funding for the Bureau of Mines increases 6% to $88 million, and for the Fish & Wildlife Service it rises 12% to $60 million.

In one of the few budget decreases, the Environmental Protection Agency's extramural R&D budget is down 8% to $186 million, with $10 million earmarked for systematic research to reduce uncertainties in risk assessment.

Janice Long, Washington

Study Revises Cancer Risk from Radon

A new National Research Council study of the health effects of radon has moved the estimate for increased risk of lung cancer deaths due to lifetime exposure more to the middle of a range bracketed by earlier studies. It also notes that most of the increased risk of lung cancer from radon exposure is in smokers.

The study, released early this month, was jointly sponsored by the Environmental Protection Agency and the Nuclear Regulatory Commission and resulted from a charge to the National Research Council's Committee on the Biological Effects of Ionizing Radiations (BEIR). In its study, the committee focused on alpha-emitting radionuclides known to induce health effects in exposed human populations. Although the study deals also with other alpha emitters—polonium, radium, thorium, uranium, and transuranic elements—the committee paid particular attention to radon and its decay products because of concern over lung cancer risk associated with increased indoor concentrations of radon in homes.

Risk estimates in the study are calculated for exposures in units of working-level months, a unit originally designed for monitoring radon exposures to underground miners. A working level is defined as any combination of the short-lived radon daughters in 1 L of air that results in the ultimate release of 1.3 × 10^5 MeV of potential alpha energy—about the amount emitted by the short-half-life daughters in equilibrium with 100 picocuries of radon. Exposure of a miner to this concentration for a working month of 170 hours (or equivalent combination) is defined as a WLM.

New study finds midlevel risk of lung cancer

Study[a]	Excess lifetime lung-cancer mortality (deaths per million person WLM[b])
Current BEIR IV (1987)	350
National Council on Radiation Protection & Measurements (1984)	130
National Research Council BEIR III (1980)	730
United Nations Scientific Committee on the Effects of Atomic Radiation (1977)	200–450

[a] Comparisons of estimates of lifetime risk of lung-cancer mortality due to a lifetime exposure to radon progeny. [b] Working-level month.

The committee estimates that lifetime exposure to a radon level of one working-level month (WLM) per year increases the number of deaths due to lung cancer by a factor of about 1.5 over the current rate for both sexes in a population having the current prevalence of cigarette smoking. In smokers, the committee finds, the risk is 10 or more times greater than that for nonsmokers.

Estimates by the committee now put the additional deaths that would occur from lung cancer at 350 for every 1 million people exposed over a lifetime to 1 WLM of radon. A 1984 study by the National Council on Radiation Protection & Measurements—used currently by many U.S. radiation experts to estimate radon lung cancer risks—placed the number at 130. And a 1980 report from the National Research Council called BEIR III estimated the excess deaths for the same exposure at 730.

The results in the current study stem from use of a new model by the committee for estimating an individual's lung cancer risk due to radon and its decay products. Previous models have depended solely on the person's total exposure. The committee employed statistical techniques that also incorporate the effects of age at exposure and time since the exposure occurred.

The committee found that lung cancer risks associated with exposure to radon increase with increasing length of exposure. It says that 15 years after exposure to radon has ended, the risk from that exposure declines to half the original risk.

The new statistical techniques were developed to analyze four major studies of radon and lung cancer. The studies looked at uranium miners in Ontario, Saskatchewan, and the Colorado Plateau, and metal miners in Sweden. But the committee cautions that its risk estimates should not be considered precise because of uncertainties affecting the estimates—from sampling variation in the primary data to misspecification of the components of the models. Most of the study's conclusions are based on studies of miners exposed to radon. The conditions under which radon is inhaled in the home may be significantly different, the committee notes.

In most homes, 4 picocuries of radon per L of air—the more common unit in this case—is equivalent to 0.02 working levels. Hence, someone living in a home with a level of 4 picocuries per L and staying at home an average of 12 hours per day would receive an annual exposure of about 0.5 WLM.

Radon-222 is the isotope of the element that has the most important impact on human health. Radon-219 (actinon), with a half-life of 3.9 seconds, and radon-220 (thoron), with a half-life of 56 seconds, occur naturally and have alpha-emitting decay products. But because of the short half-lives, concentrations are usually low. Radon-222 is a naturally occurring decay product of radium-226, the fifth daughter of uranium-238. These are present in most soils and rocks in widely varied concentrations, and thus radon gas is ubiquitous. It decays with a half-life of 3.82 days into a series of daughters. Two of the daughters—polonium-218 and polonium-214—emit alpha particles. If emission occurs in the lung, it can ultimately lead to lung cancer.

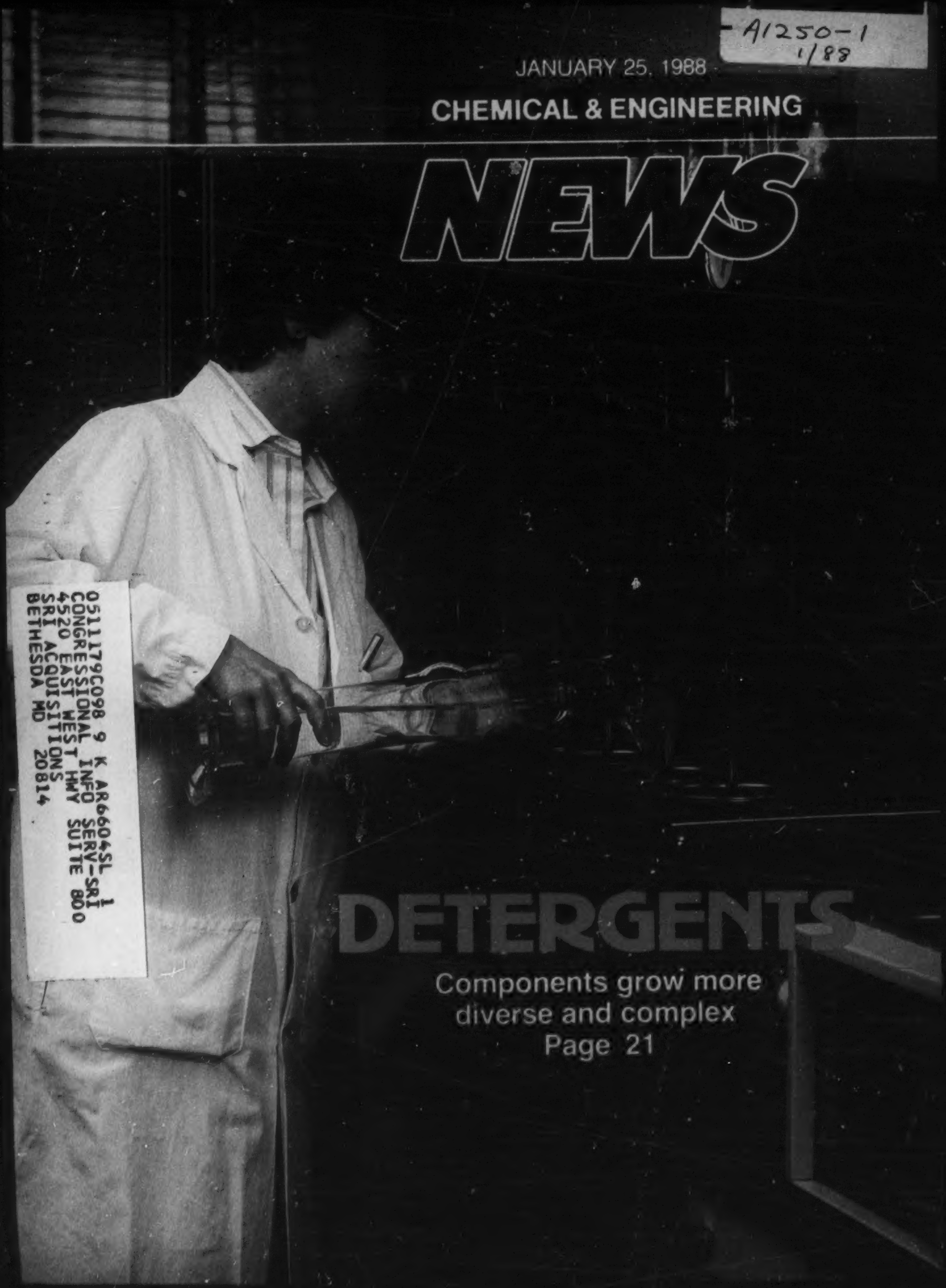
The report, "Health Risks of Radon and Other Internally Deposited Alpha-Emitters: BEIR IV," is available for $32.50 (paperbound) or $42.50 (clothbound) from National Academy Press, 2101 Constitution Ave., N.W., Washington D.C. 20418.

James Krieger, Washington

A1250-1
1/88

JANUARY 25, 1988

CHEMICAL & ENGINEERING NEWS



05111179C098 9 K AR6604SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

DETERGENTS

Components grow more
diverse and complex
Page 21

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 4
CENEAR 66 (4) 1–76
ISSN 0009-2347

JANUARY 25, 1988

News of the Week

- **Sterling Drug adopts defense tactics to fight off would-be acquirer Hoffmann-LaRoche, the Swiss-based pharmaceutical firm.** **Page 4**
- **A. H. Robins accepts American Home Products bid, reversing earlier decision to accept offer from French pharmaceutical firm Sanofi.** **Page 4**
- **Superconducting Super Collider project may face significant federal budget problems in future.** **Page 5**
- **Massachusetts Institute of Technology will phase out its department of applied biological sciences over the next year and a half to the dismay of its faculty and alumni.** **Page 6**
- **Prominent U.S. and Soviet chemists take lead role in call for comprehensive treaty that would ban all nuclear weapons tests.** **Page 6**

Cover: BASF research chemist works with Terg-O-Tometer to evaluate experimental laundry detergent formulations

Letters 2

Concentrates

Business 9
Government 13
Science/Technology 16

The Departments

New Products 45
ACS News 58
People 60
Newscripts 76

Business

Canadian plastics processing industry records a good year in 1987 as sales, profits, and volume of material processed increase. **Page 11**

Olin's earnings increase markedly in 1987, mostly as a result of ongoing restructuring program begun in 1985. **Page 12**

Government

EPA's proposed new regulations reflect comprehensive effort to protect health of all workers handling commercial pesticides. **Page 14**

NIH's recombinant DNA guidelines adjudged not violated by Montana professor's controversial inoculation of elm trees. **Page 15**

Science

U.S. scientists' human rights committees publicly protest continued unjust imprisonment of 13 Somalian scientists. **Page 17**

First sonoluminescence spectra obtained from hydrocarbon and halocarbon liquids by University of Illinois chemists. **Page 18**

Technology

Alternative energy project aims at developing new process for utilizing eastern oil shale. **Page 19**

Books

"Silent Spring Revisited" reassesses the issues raised more than 25 years ago by Rachel Carson's classic book. **Page 54**

Product Report

Detergent makeup grows increasingly diverse and complex as producers tailor products to suit needs of both household and industrial customers. **Page 21**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin

Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski

Staff Editor: Ernest L. Carpenter

Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer

Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer

Service Departments Editor: Dolores Miner

Editing Services: Anne Riesberg (Head), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)

Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos

Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 75)

LETTERS

Canadian compromise

SIR: I have participated in the discussions concerning the alternative American and European labelings of the groups in the periodic table. It appears that our efforts are likely to produce yet another recommendation whose sole virtue is that it is equally offensive to both sides.

I would like to propose a typically Canadian compromise: The rest of the world should adopt the American (ABA) labeling of the periodic table. In return, Americans will agree to spell correctly sulphur, caesium, aluminium, metre, and litre.

John S. Martin
University of Alberta, Edmonton

Women in science

SIR: My appreciation to C. Schuerch for his letter on minorities in science (C&EN, Nov. 9, 1987, page 46). It is an excellent example of how those in the majority rationalize discrimination. The fact that it exists now and can be explained, fallaciously or otherwise, does not make it any less real or tolerable.

At the risk of crossing the same line, I wish to also comment on the same Editorial, "Women, minorities, and chemistry" (C&EN, Sept. 14, 1987, page 3). It was pointed out that though "women still have no more than a toehold in graduate chemistry faculties, . . . chemistry is making tangible progress" as evidenced by the increase in the number of women earning degrees in chemistry. To me this is not evidence of progress, but of an increasing problem. The universities have been willing to take our money and benefit from our cheap labor for quite a while. It is no surprise that university programs to increase enrollments and budgets are resulting in more women undergraduate and graduate students. But, as the statistics indicate, this only increases the number of women not being hired.

Until minorities are welcomed into the faculty ranks, chemistry will remain one of the "culprits," as Erich Bloch stated.

Debra L. Mellish
Absecon, N.J.

Employment outlook

SIR: In "1988 Employment Outlook" (C&EN, Oct. 26, 1987, page 33), Bette Hileman lists falling undergraduate and graduate enrollments as problems for chemical education and reports on various proposals to address these "problems" (page 35). Yet, on page 49 we have, "A number of the new Ph.D.s are still looking for work, or else have taken postdoctoral positions only because they have failed to locate jobs in industry." Still worse, page 57 has, "If they are adjusted for inflation, salaries for chemists at all three degree levels either were unchanged or declined. The lack of change in Ph.D.s' salaries is unprecedented in the 20 years that ACS has made annual surveys of members' salaries."

With regard to problems in chemical education, my nomination for the most serious problem is that people are spending five or six years getting a Ph.D. in chemistry and then discovering that they do not have marketable skills. With regard to salaries, I point out that companies do not normally bid up the price of goods and services that are in constant oversupply. What is surprising is not that salaries are stagnant but that they have not already been stagnant for years. The cause of these situations is clear: We have too many chemistry graduates in general and too many chemistry Ph.D.s in particular.

The suggestion, discussed elsewhere in Hileman's report, to reduce the number of Ph.D.-granting institutions is a good one. ACS president Mary Good's argument to the contrary simply does not wash. She suggests that "departments ought to focus only on areas in which they can be front-runners," but with 225 institutions competing it is clear that many will be unable to be front-runners in any area.

The students may, in any case, render this point moot. Back on page 35 we also have, "The number of Ph.D.s will almost inevitably decline during the next decade or so because the pool of undergraduate majors is smaller." I see this development as a very positive one for the profession. The oversupply of Ph.D. chemists I spoke of has existed, albeit in varying degrees of severity, for at least 20 years. Could it be that supply will finally adjust to demand?

Gordon G. Cash
Southbury, Conn.

Air pollution control

SIR: I read with interest the article, "Rhine Recovers from Last Year's Sandoz Chemical Spill" (C&EN, Nov. 9, 1987, page 16). It is particularly interesting since I was at Ciba-Geigy and at BASF, Ludwigshafen, during the period Oct. 27 through Nov. 5. At BASF I had a meeting with their engineering staff in

PRODUCT REPORT

Glasses are examined for traces of spotting and filming from dishwashing detergent at BASF lab in Wyandotte, Mich.

Detergent Components Become Increasingly Diverse, Complex

Bruce F. Greek, C&EN Houston

The demands of the marketplace make surfactants an ever-changing business as the needs of both household and industrial customers force producers to tailor their products.

Extensive research and development by surfactant producers and detergent formulators has broadened the uses of surface active agents. Materials in detergents and other cleaners have become ever more diverse and complex as producers move to meet stringent demands of consumers.

A wide variety of cleaners and other products having surface active properties currently are used by household and industrial/institutional consumers. But growth in demand for surfactants will slow in 1988 and remain only slightly above the average growth rate of the previous decade or so. Markets for detergents and other surfactant products already are greatly fractionated and probably will become even more so as consumers take to new products when they hit the marketplace.

Surfactants occupy a large segment of the chemical industry, and marketing success of this segment stems from the very heterogeneity of the products containing surfactant materials. No one formulation, detergent, or surfactant fits every use. Inventory of cleaning materials in a typical household might include half a dozen or more formulated products designed to be the most suitable for a specific job, whether cleaning clothes, floors, or automobiles.

In industrial and institutional markets, many surfactant materials find their way to more than just cleaning jobs. For example, they are widely used to separate oil from water in enhanced oil recovery. They also are used in making emulsions of tar and water for quick application and for subsequent demul-

Makeup of powdered heavy-duty laundry detergents

Functional agent	Typical materials	Range of use, %
Surfactant (anionic/cationic/nonionic)	Alkylbenzene sulfonates	0 to 20%
	Fatty alcohol ether sulfates	0 to 15
	Alkyl or nonylphenol polyethylene glycol ethers	0 to 15
Builders (chelating agents)	Sodium tripolyphosphate	0 to 50
Ion exchangers	Zeolites, polyacrylic acids and derivatives	0 to 60
Alkalies	Sodium carbonate	0 to 35
Bleaches	Sodium perborate/percarbonates	0 to 5
Fabric softeners	Quaternary ammonium salts	0 to 5
	Clays	0 to 5
Anticorrosion materials	Sodium silicate	0 to 25
Antiredeposition materials	Cellulose ethers	0 to 0.5
Enzymes	Proteases, amylases	0 to 2
Optical brighteners	Stilbene derivatives	0 to 0.25
Fragrances, dyes	—	0 to tiny
Fillers	Sodium sulfate	Balance

sion to bind the tar to gravel in building roads. The industrial and institutional markets also are changing, possibly more rapidly than the household markets, as industry changes its processing and manufacturing methods.

Because the end products of detergent materials are diverse and frequently overlapping, clear-cut definitions of the markets are elusive. It's estimated that more than half the consumption of the materials is by industrial and institutional users (50 to 60%), and more than another quarter goes into household cleaning products (25 to 30%). The remainder goes into personal care products such as cosmetics, shampoos, and toilet soap.

Consumption of detergent materials is difficult to estimate because the formulations are so varied. Household laundry detergents (the largest segment in household consumption) have compositions that include surfactants (the surface active agent itself), builders (chelating agents), bleaches, and numerous additives, all designed to meet the many objectives for which a detergent can be used. The volume of all the kinds of materials that become part of the products that have surface active properties now probably ranges from 25 million to 50 billion lb. This includes active and inert ingredients.

Production and sales data on all kinds of the surfactants alone are available, whether used in cleaning agents or other applications. In 1986, the latest year for which complete data are available, U.S. production of surfactants totaled almost 5.9 billion lb, according to the U.S. International Trade Commission (ITC). That output is 35% more than the 4.37 billion lb reported by ITC for 1982. It also is almost 10% more than production in 1985.

In 1982, however, production fell 14% from about 5.1 billion lb the year before, which reflected the effect of that year's recession. Recovery from the recession slowed in 1985 with a small decline in production that resulted partly from reformulation of many household laundry products, which, in turn, reduced surfactant demand. Allowing for variations due to the economic and formulation factors involved, the average annual growth in production of surfactants during the 1980s has been less than 3%. Because the base is so large, the 3% growth amounts to well over 150 million lb a year. Counting other materials sold with the surfactants in formulated products, the volume addition totals several times that of the surfactants.

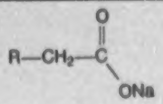
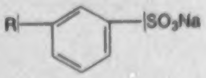
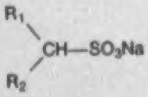
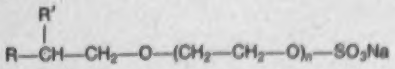
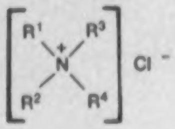
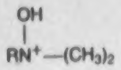
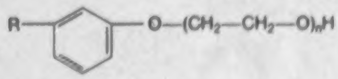
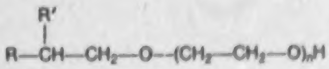
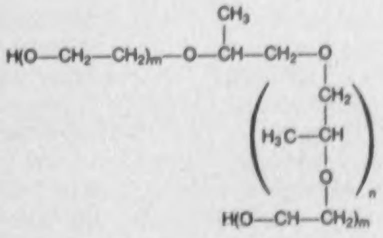
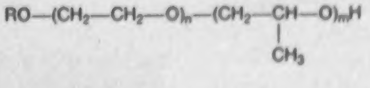
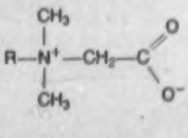
Surfactants production last year grew about 4% from 1986. That relatively strong growth was a result of an upbeat economy most of the year and of new product development by surfactant manufacturers and by detergent formulators and marketers. The outlook for 1988 is not as bright because fewer new products are expected to be added as a consolidation of last year's introductions goes on. Surfactants production this year likely will poke along in the 2 to 3% growth range, assuming the general economy holds up.

The immense diversity in production of surfactants also is reflected in ITC data. In 1986, production and/or sales of about 1200 different chemical compounds or groups of compounds as surface active agents were reported. About 170 different companies are represented in the reports. No one compound or compound group exceeded 1 billion lb of production. More than 62% of the production in 1986 was of anionic surfactants, almost 29% was nonionic, and less than 9% was cationic. A small quantity—27.3 million lb—of amphoteric surfactants was reported, or less than 0.5% of total production.

The 1986 surfactants sales reported to ITC totaled more than 3.5 billion lb, with a total value of more than $1.6 billion. The average unit value was 45 cents per lb. In 1985, sales of surfactants exceeded 3.3 billion lb, valued at nearly $1.6 billion, and having an average unit value of 47 cents per lb. Not surprisingly, the low-volume amphoteric surfactants in 1986 had the highest unit value at $1.07. The workhorse anionic surfactants averaged 30 cents per lb, the cationics nearly $1.00 per lb, and the nonionics averaged 50 cents per lb.

Merchant suppliers of surfactants account for more than 60% of production. That group includes most of the large chemical companies and many small specialty producers. The large formulators of detergents—Church & Dwight, Colgate-Palmolive, Lever Brothers, and Procter & Gamble, as well as numerous smaller specialty and private label formulators—also make some of their surfactants. The latter group of producers may sell part of their production to other formulators. Many other companies also produce the basic ingredients of surfactants. Some make ethylene, propylene, and benzene, which are key petrochemical raw materials of surfac-

Surfactants fall into four major chemical groups

ANIONICS		
Carboxylates (soaps)	 $R{-}CH_2{-}C(=O){-}ONa$	$R = C_{10-16}$
Alkylbenzene sulfonates		$R = C_{10-13}$
Alkane sulfonates		$R_1 + R_2 = C_{11-17}$
α-Olefin sulfonates	$H_3C{-}(CH_2)_m{-}CH{=}CH{-}(CH_2)_n{-}SO_3Na$	$n + m = 9-15$
Fatty alcohol sulfates	$R{-}CH_2{-}O{-}SO_3Na$	$R = C_{11-17}$
Oxo-alcohol ether sulfates	 $R{-}CH(R'){-}CH_2{-}O{-}(CH_2{-}CH_2{-}O)_n{-}SO_3Na$	$R + R' = C_{11-13}$ $n = 1-4$
CATIONICS		
Quaternary ammonium salts (quats)		$R^1, R^2 = C_{16-18}$ $R^3, R^4 = C_1$
Amine oxides	 $RN^+(OH){-}(CH_3)_2$	$R = C_{12-18}$
NONIONICS		
Alkylphenol ethoxylates		$R = C_{8-12}$ $n = 5-10$
Fatty or oxo-alcohol polyethyleneglycol ethers	 $R{-}CH(R'){-}CH_2{-}O{-}(CH_2{-}CH_2{-}O)_nH$	$R = C_{6-16}$ $R' = H, C_1, C_2 \ldots$ $n = 3-15$
Ethylene oxide-propylene oxide polymers		$n = 2-60$ $m = 15-80$
Fatty alcohol polyglycol ethers	 $RO{-}(CH_2{-}CH_2{-}O)_n{-}(CH_2{-}CH(CH_3){-}O)_mH$	$R = C_{8-18}$ $n = 3-6$ $m = 3-6$
AMPHOTERICS		
Alkyl betaines (also sulfonated)		$R = C_{12-18}$

tants and many other products. Some of these companies make surfactant materials that are several steps beyond the basic petrochemical.

For example, ethylene producers BASF, Shell Chemical, Texaco Chemical, Union Carbide, and Vista Chemical make first-step intermediates such as ethylene oxide, α-olefins, and various detergent alcohols that subsequently are made into surfactants. These and other companies such as Ethyl and Sherex Chemical either sell the intermediates or further process them into surfactants to be blended into detergents and other products.

The number of surfactants and intermediates for surfactants offered by basic producers continues to grow as consumers search for more specificity in the detergent or other product for the final market, says Jerry G. Moffet Jr., business manager of detergent products at Shell Chemical. For example, he says that Shell offers many more individual items than previously in its product line of ethoxylates. These ethoxylates differ in the numbers of ethylene oxide groups in them, thereby providing different final surface active properties.

A similar viewpoint comes from Walter Whitla, who formerly was manager of marketing for detergent materials with Akzo Chemie America and is now corporate director of purchasing. He says that 50% of 1987 sales volume came from products that the company did not offer three years ago, many of which are the result of the company's R&D programs. Akzo has been particularly pursuing development and sales of various new kinds of fabric softeners and antistatic agents that are blended into household and other detergent formulations as auxiliary materials to surfactants.

The expansion of product lines in surfactant and auxiliary materials, largely through R&D but also through purchase of part or all of other companies, is for many companies a long-term characteristic of the detergent materials industry. The entire industry related to surface active products has long been known to be among the most creative parts of the chemical industry—

and, according to some, among the most creative of all industries. The enormous product lines offered by the 200 or more companies that are part of this business have developed through efforts to find new products to fit old uses in better ways and through finding new uses for old products, some of which may be 100 years old or less than five.

Product line expansions affect companies differently. Some new products can be added by changing plants through relatively minor equipment and processing modifications. Others require new units if the anticipated sales volume is large. For example, BASF is adding a unit at its Spartanburg, S.C., plant to increase its line of acrylic acid-based homopolymers and copolymers, according to Kenneth F. Schoene, director of performance chemicals business at BASF Corp.'s chemical division. Such polymers are used as functional additives such as anti-redeposition and anti-incrustation agents or as processing aids in the manufacture of powder household detergents. The unit is scheduled to begin operating in mid-1988.

Behind expansion of product lines to fit demands for surfactant and other materials are competitive pressures on sellers of the final product, whether it goes into household, industrial, or institutional markets. As a result, formulations are changed and products frequently added or withdrawn.

Factors other than surface active properties or whiteness of clothing after washing strongly influence demand for detergent materials. For example, convenience is a factor currently affecting formulations. Single-use packages are finding growing acceptance, as are liquid detergents. A complete material is the keystone of meeting the convenience demand: a material that not only cleans, but bleaches, softens, and gives a good "hand" or feel to the clothes after drying, while having a good shelf life and smelling nice too. Not to be neglected are material and packaging costs, which account for roughly 55 cents of every dollar from sales of formulated surfactant products, according to a market study done by Business Trends Analysts of Commack, N.Y.

Technical specialists at BASF's Wyandotte lab use Terg-O-Tometer, computerized reflectance, and other measurements to test laundry and other formulations

Despite demand for convenience, low cost, light weight, ease of handling (part of the reason behind the growing acceptance of liquid household detergents), and other requirements in cleaning formulations, the product nevertheless must do its job as well as or better than another or it soon will be left on the supermarket shelf. That situation means concentration on development of surfactant materials themselves, and (to a lesser degree but not insignificantly) emphasis on builders, bleaching agents, brighteners, and other auxiliary materials that can go into the many formulations.

Surfactants began with a form of soap (salts of carboxylic acids) made as long ago as 2500 BC by the Sumerians living in what is now the countries of Iraq and Iran. Since then, most major civilizations have known some kind of soap, made with slowly growing technical competence. Late in the 18th century, according to H. Verbeek of Henkel in West Germany, an understanding of the structure of fats, a method to make soda ash, and a system to bring large quantities of low-cost vegetable oils from the tropics put soapmaking on a broad technical scale. As the 20th century began, some compounds similar to cur-

Surfactants have characteristic properties

Amphipathic structures. Surfactant molecules are made up of groups of opposite solubilities, such as oil-soluble and water-soluble groups.

High solubility. Surfactants are highly soluble in at least one phase of a liquid system.

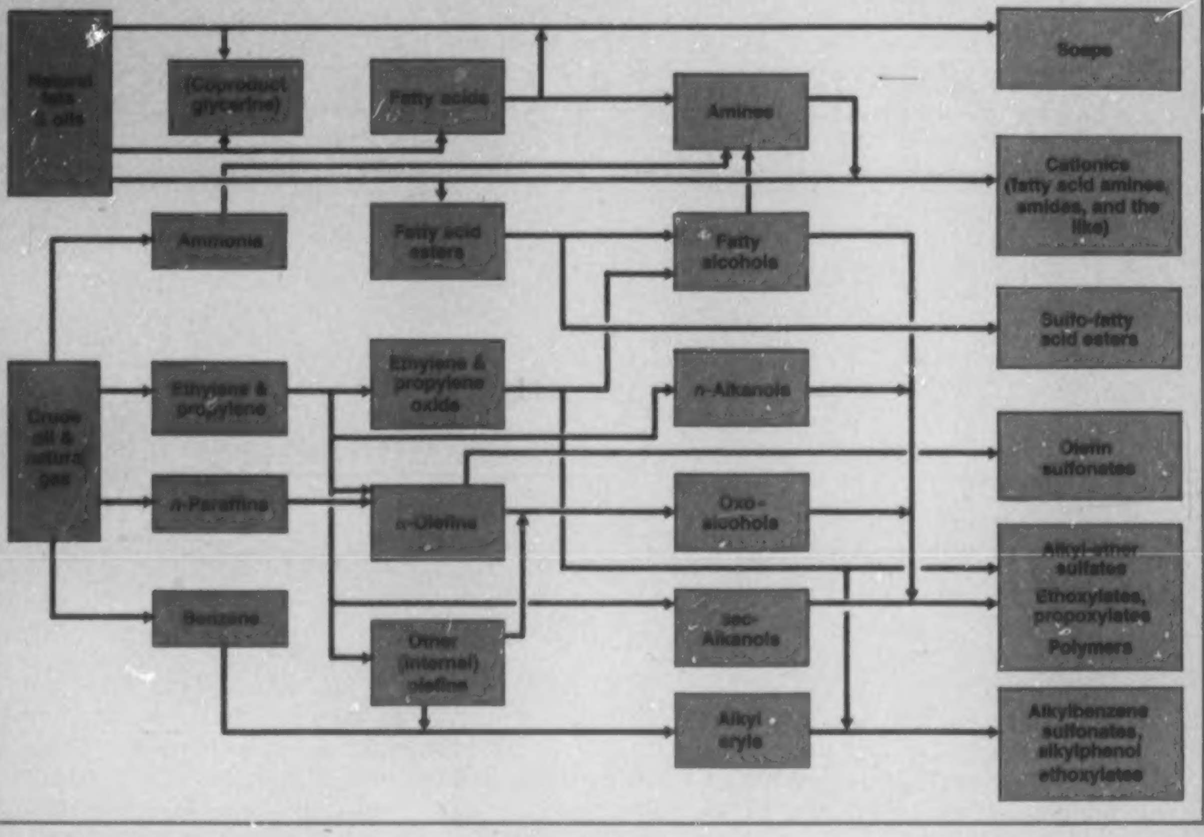
Interfacial adsorption. Surfactant solute at equilibrium is more concentrated at phase interface than in bulk solution.

Interfacial orientation. Surfactant molecules and ions are in oriented monolayers at phase interfaces.

Micelle formation. Surfactants aggregate into micelles or groups of molecules or ions if concentration of surfactant in the bulk solution exceeds a characteristic limiting value, the critical micelle concentration, which is specific for any surfactant-solvent system.

Functional properties. Surfactant solutions have combination of detergency (cleaning), dispersing, emulsifying, foaming, solubilizing, and wetting properties.

Surfactants manufacture involves variety of steps


Natural fats & oils
(Coproduct glycerine)
Fatty acids
Amines
Soaps
Cationics (fatty acid amines, amides, and the like)
Ammonia
Fatty acid esters
Fatty alcohols
Sulfo-fatty acid esters
Crude oil & natural gas
Ethylene & propylene
Ethylene & propylene oxide
n-Alkanols
Olefin sulfonates
n-Paraffins
α-Olefins
Oxo-alcohols
Alkyl-ether sulfates
Ethoxylates, propoxylates
Polymers
Benzene
Other (internal) olefins
sec-Alkanols
Alkyl aryls
Alkylbenzene sulfonates, alkylphenol ethoxylates

rently used surfactants had been made in Germany, but most performed unsatisfactorily as detergents. By the 1930s, a variety of fatty alcohol sulfates were marketed commercially in detergents. Thousands of compounds with amphipathic structures—molecules with groups of opposing solubilities such as an oil-soluble hydrocarbon chain and a water-soluble ionic group—have been made since then.

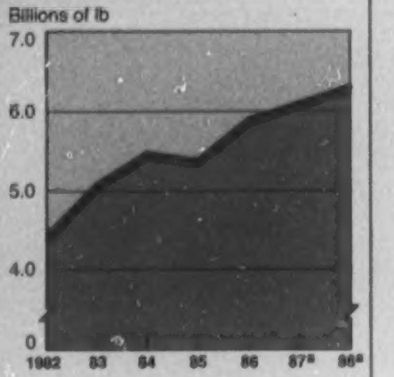
Because of their nature, most soaps are classified as anionic surfactants. Classification depends on the charge on the surface active part of the molecule, usually the larger part. The long hydrocarbon chain derived by splitting tallow and other natural fats or coconut and other natural oils into a hydrocarbon acid and glycerine provides the negative charge. Sodium or another alkali atom provides the positive charge. Most soap commercially made today is sold as the major component of toilet bar soap for personal use and for a host of industrial detergent formulations. In household and other detergents, soap has long been replaced by more effective surfactants, except for specialized uses such as a foam regulator.

Useful production estimates of soaps as formulated are unavailable. Production of carboxylic acids and salts in 1986 totaled about 760 million lb, according to ITC. Sodium salts of tallow acids accounted for slightly less than 370 million lb, or about 50% of the total production of carboxylic acids and salts. These materials were about 10% of the 3.66 billion lb of anionic surfactants produced in 1986. The outlook for growth of soaps is less rosy than for surfactants in general because other surfactants continue to capture some markets from soap and because use of soap depends heavily on the personal care products markets, which have heavy competition from many kinds of cleaning products.

Sulfonic acids and their salts are the dominant part of the anionic surfactant business. Almost 2.1 billion lb of these materials were made in 1986, up 17% from about 1.8 billion lb produced in 1985. Several major groups of products make up the sulfonic acid and salts share of anionic surfactants. Largest is the ligninsulfonates and naphthalenesulfonates group. Next is the group of sulfuric acid esters, closely followed by the alkylbenzenesulfonates.

As their name implies, ligninsulfonates are made from the lignin in wood by the simple reaction of sulfur dioxide and calcium sulfite. In 1986, the production of ammonium, calcium, and sodium salts of ligninsulfonates totaled more than 850 million lb, or more than 90% of the group of lignin- and naphthalenesulfonates. Most are used as inexpensive dispersing agents in industrial applications such as ore flotation and oil well drilling. Whether these products grow depends on those two industries, both of which currently are operating below nor-

Surfactant output to hit 6.3 billion lb this year



a Estimate. **Sources:** International Trade Commission, C&EN estimates

mal levels. Production of these sulfonates was down in 1986, reflecting that condition. The outlook for 1988 is for a minor increase from the 1986 level of production.

More than 770 million lb of sulfuric acid esters were produced in 1986, according to ITC, most based upon either linear alcohols with chains of 12 to 18 carbons or upon ethoxylated alcohols, which are sulfonated with sulfur trioxide or chlorosulfonic acid. Sources of those alcohols are either natural coconut oil or ethylene polymerization using Ziegler technology. The choice of feedstock to be used for making the alcohols depends on cost of the ethylene (crude oil prices) compared with cost of the coconut oil and the supply situation for coconut oils. Ethoxylation of the alcohols with varying quantities of ethylene oxide produces alcohol ether sulfates.

The alcohol sulfates often have been regarded as the first of the modern synthetic detergents, although they have been used commercially for more than 50 years. If a builder such as sodium tripolyphosphate can be used with them in a detergent formulation, then the performance of the formulation is acceptable for many household laundry detergents. If no phosphates are used, then sulfated alcohol ethyoxylates are combined with the alcohol sulfates to improve the final performance. These kinds of alcohol sulfates contain a wide range of ethylene oxide groups, depending on the kinds of end uses for which they are designed.

More than 80% of the production of the various alcohol sulfates goes into various kinds of household and personal care cleaning products. The actual formulations vary widely because, for example, some are aimed at low-cost laundry products, either powdered or liquid, and others are aimed at hair shampoos and hand dishwashing materials, because such materials are known to have little effect on skin.

A number of other alcohol derivatives are produced in relatively small quantities for specialized uses. Some of the derivatives are available as relatively pure compounds, and others are available as mixtures of several alcohols. The alcohols themselves are produced either from ethylene or from natural oils.

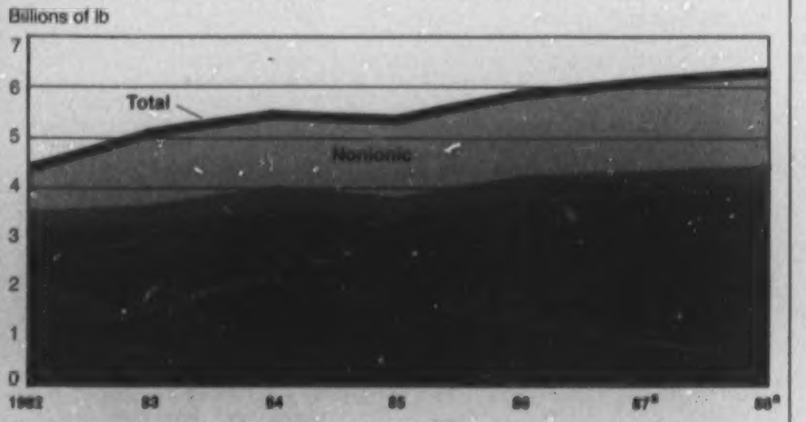
In 1986, more than 750 million lb of linear alkylbenzene sulfonic acids and sulfonates were produced. Three compounds accounted for well over 90% of that total—dodecylbenzenesulfonic acid, and the sodium salts of this acid and of tridecylbenzenesulfonic acid. Reported production of these materials apparently increased greatly during 1986 from 1985 output of less than 570 million lb. However, industry sources suggest that, for some time, reported production has been below actual production, but that improvements in reporting and assembling data now make the reported value closer to the true quantity.

Several large producers and detergent makers produce their own linear alkylbenzene sulfonates (LAS) for captive use; only 20 to 30% of total production is sold on the merchant market. Household laundry and dishwashing products long have dominated LAS use and were the major outlet a number of years ago when the alkyl chain was branched instead of linear. Because biodegradation of branched-chain alkylbenzene sulfonates took so long, these materials caused foaming in wastewater treating plants and in bodies of water receiving them and so are not usually used in household laundry detergent formulations anymore.

Frequent reformulations of household detergents and other products cause some shifting in the kinds and quantities of LAS used. In general, however, production of these kinds of sulfonates has trended downward during the 1980s, as they have been partially replaced by various alcohol sulfates. Outlook for LAS in household and personal care uses appears to be one of slow decline, but is one of slow increase in industrial markets. The net effect will be one of slightly lower output, because industrial uses are only about 25 to 35% of total consumption.

A large number of other compounds with surface active properties fall into the anionic classification. Most are produced in far small-

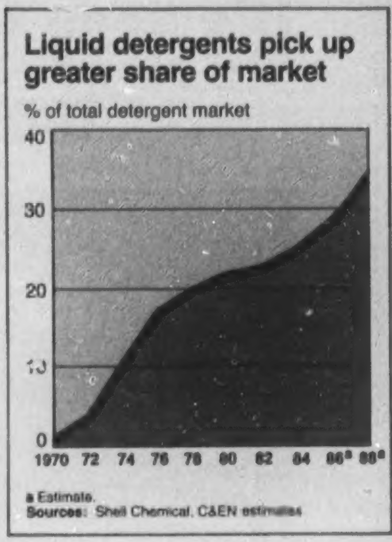
Output of nonionics growing faster than other types



a Estimates (smaller quantities of amphoteric surfactants, less than 30 million lb per year, excluded).
Sources: International Trade Commission, C&EN estimates

er quantities than are the three big-volume sulfonic acid salts, and they cost more on a unit basis. Sulfonates of such aromatics as benzene, toluene, cumene, and xylene; dialkyl sulfosuccinates; and numerous phosphate esters are among the larger-volume other products. Most of these compounds have many uses in industry where their cost and various limitations on the conditions under which they are most effective are less important than in the competitive retail markets of household detergents. For example, the phosphoric acid derivatives find use in polymerizations, clothes dry cleaning, textile processing, and pesticide dispersion. Volume growth of this catch-all group of anionic surfactant materials is expected to be spotty. Those anionic surfactants with a special value to a rapidly growing segment of industry will show substantial growth from a relatively small base. As a group, these compounds will grow more slowly than will the alcohol sulfates.

Cationic surfactants, with slightly more than 492 million lb produced in 1986, account for less than 10% of surfactant production, according to ITC. As their name suggests, cationic surfactants have a positive charge on their hydrophobic group. The charge is on the nitrogen atom in an amine or a quaternary ammonium compound. A large number of amines, amine oxides, their salts, and quaternary ammonium salts are produced in small quantities.



a Estimate.
Sources: Shell Chemical, C&EN estimates

Quaternary ammonium salts that do not contain oxygen made up almost one third of cationic surfactant production in 1986. Small quantities of these salts that do contain oxygen also were produced. As a group, quaternary ammonium salts have two distinctly different uses. In household products, they are used as fabric softeners because the positive charge on the quaternary ammonium ion causes strong adsorption on fabrics that generally have a negative charge. This property also makes these compounds useful as antistatic agents in detergent formulations.

Heavy-duty detergents find use in commercial laundries

Put Our Heads On Your Foam Problem.

The antifoam experts at Dow Corning will find the answers.

And recommend the right antifoam agent from our broad line. Whether your problem is with high or low pH. Or with high temperature. Or for food-related uses. For both aqueous and non-aqueous systems.

Remember, our antifoams are concentrated to go a long way, and last a long time.

For samples or answers from the antifoam experts...

Call
1-800
FOAM
FREE

Or write: Dow Corning Corporation,
Dept. A-7016, Midland, MI 48686-0994.

DOW CORNING®

©1987 Dow Corning Corporation.

CIRCLE 33 ON READER SERVICE CARD

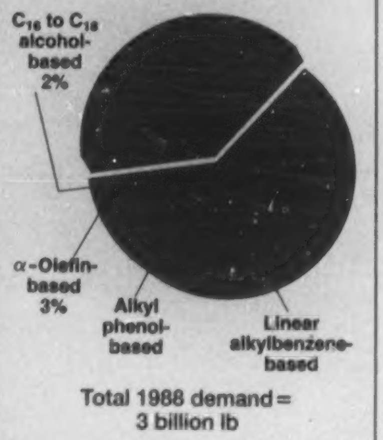
CIRCLE 17 ON READER SERVICE CARD →

In industrial and institutional uses, quaternary ammonium compounds also find use in ways other than as a surfactant because of some of their germicidal and lubricating properties. Because of their ability to reduce static charge and impart a soft feel to fabrics, quaternary ammonium compounds find most of their industrial uses in textile manufacturing.

The largest volumes of those compounds for which production is reported are based on natural fats and oils such as tallow and coconut oil. Production of quaternary ammonium compounds increased about 10% in 1986 over 1985. The growth in 1987 probably was as good because of various introductions of new derivatives. But growth this year could slow because fewer new products are expected to be introduced.

The other large categories of cationic surfactants are the various amines and amine oxides. More than 100 million lb of amine oxides without amide linkages were produced in 1986. Production of amines without oxygen atoms was almost 150 million lb in 1986. Another 30 million lb of amine and amine oxides with amide linkages also were produced. Growth in production of these amino cationic surfactants was significant in 1986, rising as much as 40% in the case of the group of monoamines.

Soap remains most widely used surfactant



Total 1988 demand = 3 billion lb

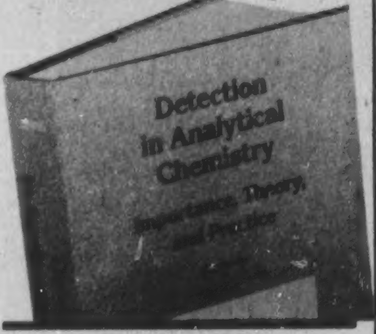
Sources: Shell Chemical, C&EN estimates

Outlook for production of this group of surfactants depends heavily on the economic conditions that affect industrial production, because the major uses of the amine surfactants are largely in applications such as ore flotation agents, corrosion inhibitors, dispersing agents, wetting agents for asphalt and tar emulsions, and as intermediates in making even more complex derivatives. Amine oxides do go into household products, particularly where additional foam is desired in the washing process, such as in hand dishwashing. They also are used in textile processing, particularly if cotton fibers are involved. Ethoxylated amines find much the same uses in general, but often are specifically tailored for certain uses in the textile industry. Imidazoline derivatives of many kinds also find special application in many of the same uses.

Of the third major type of surfactant, nonionics, more than 1.72 billion lb were produced in 1986, up about 10% from 1985. By far the largest group are the various ethers, produced mainly by ethoxylating alkyl phenols and linear alcohols. These accounted for about 73% of the total. Carboxylic acid esters production totaled 290 million lb, or 17%, and carboxylic amines accounted for less than 10% of production.

The ethers output is dominated by ethoxylated linear alcohols, which accounted for more than 55% of 1986 ethers production. The number of ethylene oxide molecules added to a long-chain alcohol varies widely—possibly by a difference of 50 over the whole line of products—as a result of varying rates of reaction during the ethoxylation process. The broad spectrum of homologs resulting from the ethoxylation reactions roughly follows a Poisson distribution. Depending on their chain length, these ethoxylated alcohols are superior in emulsifying, wetting, and dispersing properties. However, the better surfactant properties result from a relatively few ethylene oxide groups in the molecule. To minimize production of the nonbenzenoid ethers having too few or too many of the groups, considerable catalyst work has been done to keep the distribution as nar-

Detection in Analytical Chemistry
Importance, Theory, and Practice



This new book explores the meaning of detection in chemical measurement science from both fundamental and practical perspectives, and addresses the issue of detection from the most extensive user community of detection limits. You'll examine those fundamental characteristics of the chemical measurement process which must be taken into account to derive meaningful detection limits. You'll better understand the care and energy involved in devising methods of extreme sensitivity, including method characterization and potential sources of error. You'll read discussions of real world problems and needs for meaningful detection, both in the laboratory and in the regulatory environment. The seventeen chapters focus on four major areas:

- **Sociopolitical Perspectives**
- **Fundamental and Comparative Aspects of Detection**
- **Detection Limits in Practice: Characterization and Application of Ultrasensitive Methods**
- **Panel Views of Some Critical Issues**

Detection in Analytical Chemistry promotes communication on the subject of detection results between the public and the technical community, and within the technical community. All scientists who need to assess actual detection capabilities, or to design methods capable of meeting specified detection limits will find this book an invaluable resource.

Lloyd A. Currie, *Editor*

Developed from a symposium sponsored by the Divisions of Analytical Chemistry, Environmental Chemistry, and Nuclear Chemistry and Technology of the American Chemical Society

ACS Symposium Series No. 361
338 pages (1988) Clothbound
ISBN 0-8412-1445-X LC 87-30735
US & Canada **$64.95** Export **$77.95**

Order from: American Chemical Society
Distribution Office Dept. 78
1155 Sixteenth St., N.W.
Washington, DC 20036

or CALL TOLL FREE

800-227-5558

and use your credit card!

PRODUCT PROSPECTUS

Na

Sodium Dispersions

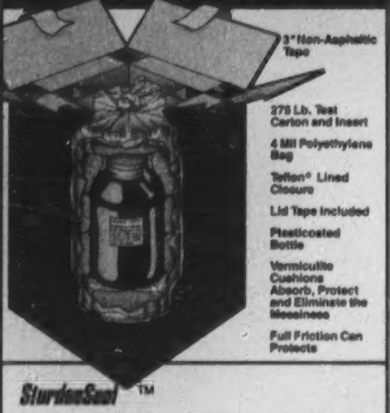
Available in standard formulations or custom blended to your requirements.

Call Tom Pletzke (201) 867-4100 or use the Reader Service Number for information, specifications or prices.

Matheson®
Secaucus, NJ 07094

CIRCLE 48 ON READER SERVICE CARD

SHIP HAZARDOUS MATERIALS VIA UPS, FEDERAL EXPRESS AND AIR CARGO


3" Non-Asphaltic Tape
275 Lb. Test Carton and Insert
4 Mil Polyethylene Bag
Teflon® Lined Closure
Lid Tape Included
Plasticoated Bottle
Vermiculite Cushions Absorb, Protect and Eliminate the Messiness
Full Friction Can Protects

SturdeeSeal™
HAZARDOUS MATERIAL SHIPPER
Patent Pending
No Exterior Warning Label necessary for domestic shipments. D.O.T. Exemption E-9168 permits UPS®, Federal Express®, United Nations International and U.S. air cargo shipping.

NO EXTERIOR WARNING LABEL

All-Pak

All-Pak, Inc. • 2260 Roswell Drive
Pittsburgh, PA 15205 • Phone: (412) 922-7525

CIRCLE 43 ON READER SERVICE CARD

Get the latest info on DMAP!

New 28-page booklet on 4-DMAP (4-dimethyl-amino-pyridine) reviews the latest technology using this versatile chemical. Applications discussed include catalysis, pharmaceutical intermediates, and numerous other organic syntheses.

Get the facts on how DMAP can help you. Call or write today for your free copy.

NEPERA

Nepera, Inc., Route 17
Harriman, NY 10926
(914) 782-8171
TWX 5102494847

CIRCLE 12 ON READER SERVICE CARD

Massachusetts Institute of Technology presents a short course entitled:
"ADVANCES IN CONTROLLED RELEASE TECHNOLOGY: POLYMERIC DELIVERY SYSTEMS FOR DRUGS, PESTICIDES, AND FOODS"

Dates: June 13 – June 17, 1988
Professor Robert Langer, MIT—Program Director
Professor Frank Harris, University of Akron
Dr. Jorge Heller, SRI International
Professor Marcus Karel, MIT
Professor Nicholas Peppas, Purdue University
Professor Frank Szoka, University of California, S.F.

Location: MIT, Cambridge, Mass.

Contact: **Pamela Brown**
MIT, E25-342,
Cambridge, MA 02139;
Tel: (617) 253-3123;
TELEX 92173 MITCAM

Attendance Fee: $1200.

Topics:
- Controlled Release of Polypeptides/Macromolecules
- Bioerodible Polymers
- Bioadhesives
- Oral and Injectable Systems
- Transdermal Systems
- Regulatory Approval Studies
- Liposomes
- Monoclonal Antibodies
- Microcapsules and Microcarriers
- Specialty Polymers

CIRCLE 11 ON READER SERVICE CARD

row as possible around a desired number.

More than three quarters of consumption goes into various household laundry detergents or other household cleaners. The biggest single household use continues to be liquid laundry detergents. Because growth in demand has rekindled for liquid detergents, demand for the alcohol ethoxylates is expected to continue rising at 4 to 6% in 1988, or well above the average growth rate for all surfactants.

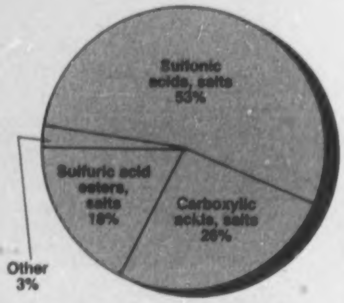
A large number of other nonbenzenoid special ethers are made for use as surfactants, but none is produced in the quantities that are produced as mixed ethoxylated linear alcohols. Some of the types of these products are ethoxylated polypropylene glycol, ethoxylated mixed ethylene and propylene glycol, or ethoxylated C_{10} to C_{18} alcohols. Often, they are used in particular industrial applications and are worth the high costs.

Among the benzenoid ethers, ethoxylated nonylphenol dominates. It accounted for more than 75% of 1986 production. Manufacture of these esters follows similar processes and uses equipment similar to that

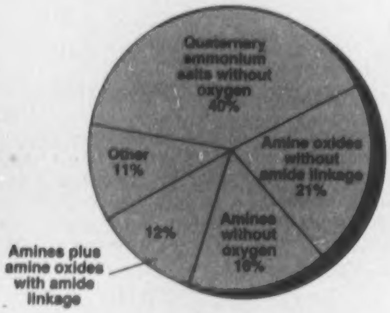
Surgeon scrubs with specialty soap

Product mix of surfactants changes slowly

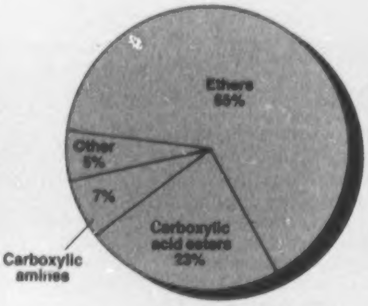
For 1982 . . .



Anionic total output = 3.06 billion lb

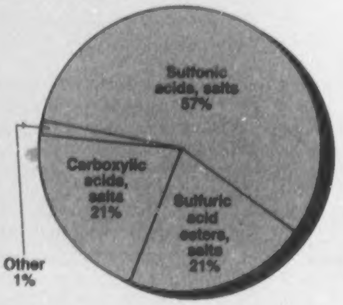


Cationic total output = 390 million lb

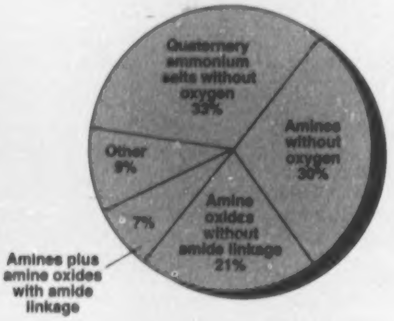


Nonionic total output = 910 million lb

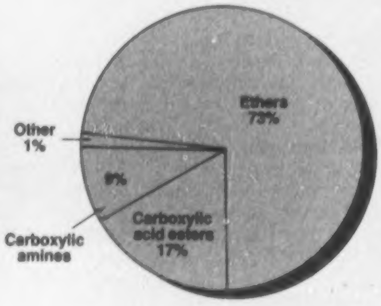
For 1986 . . .



Anionic total output = 3.65 billion lb



Cationic total output = 490 million lb



Nonionic total output = 1.72 billion lb

used in manufacture of linear alcohol ethoxylates. As a result, several of the producers of these materials also make linear alcohol ethoxylates. The carboxylic esters have marginally better detergency properties but have a problem in slow biodegradability. Consequently, industrial uses predominate and they are expected to continue to do so. Outlook for growth of these esters, therefore, depends on industrial production and on mineral and oil production.

A large number of fatty acids, alcohols, glycols, and glycol polymers are used in the manufacture of esters of carboxylic acids. Various esters of glycerol, of polyethylene glycol, of anhydrosorbitol, and of several natural fats are examples produced in significant quantities. Numerous kinds of these esters are ethoxylated to improve their surfactant properties. Many of the carboxylic acid esters have been approved for use in foods and are widely used as emulsifiers and dispersing agents in bakery products, candies, and dairy products. Others are used in cosmetics and pharmaceuticals. Various industrially used esters are prevalent in such areas as metals fabrication, polymerizations, paint manufacture, and textile processing.

Production of the carboxylic acid ester surfactants in 1986 rose about 12% from 1985 to 290 million lb. In 1987, growth fell to a slightly slower pace of about 10%. A similar rate is expected for 1988, unless the economy slows, with a resultant decline in sales of luxury foods, clothing, and durable goods.

Carboxylic acid amines, with a 1986 reported production total of 153 million lb, are made by reacting fatty acids with hydroxyalkyl amines, mostly diethanolamine. Some of the products are relatively insoluble in water, but they are used in combination with more hydrophilic surfactants. Their uses range from liquid dishwashing detergents to textile processing aids and drycleaning detergents. Growth has been spotty, because individual compounds or limited range groups of compounds vary in demand as the technology of use changes.

The small quantities of amphoteric surfactants produced in the U.S. are based mostly on derivatives of betaine—trimethyl ammonium acetate. A basic nitrogen group and an acidic carboxyl group are the predominant functional parts of these compounds. High cost limits their use to specialty products, many of which are cosmetics. It is expected that growth of amphoteric surfactants will be slow.

Many other components besides surfactants are used in detergents. In household detergent formulations, for instance, the list of components can be long. These components augment the properties of surfactants. Although not universally agreed upon, the component next in importance to the surfactants is the builder. The most important action expected from a detergent builder is to remove metallic ions such as calcium and magnesium, or the "hardness" from the washing fluid. Builders can do this by sequestering these ions (chelating them), precipitating them as insoluble salts, or exchanging them for sodium ions. Builders also can provide alkalinity to the washing media and provide some suspension effect to keep loosened soil particles in the media.

A dozen or more materials are or have been used to some extent as builders in detergent formulations. All have one or more drawbacks that offset their value in the formulations. Sodium tripolyphosphate long has been considered by the industry as the best builder. Its major difficulty comes from its contribution to eutrophication of bodies of water as a result of the fertilization of algae by phosphorus atoms. Now, about 28% of the U.S. has banned phosphate materials from detergent formulations, and those regulations may grow, according to Business Trend Analysts.

Alternatives for sodium tripolyphosphate are widely used by detergent formulators. Compositions and materials change frequently as development work attempts to improve performance of cleaning while offering greater convenience in handling, as well as keeping materials cost as low as possible. One such alternative, sodium citrate, sequesters calcium and magnesium ions much less effectively than does sodium tripolyphosphate. However, it has found growing use because of its high solubility and the increasing demand for liquid laundry detergents. Although cost of sodium citrate has declined significantly, it still is more expensive than sodium tripolyphosphate.

Know all the rules for surfactants???

Here's one that breaks every rule...

Rule 1. Oily soils reduce the lather.
HAMPOSYL® Surfactants actually lather better in the presence of oily soils.

Rule 2. Water hardness inhibits lathering.
HAMPOSYL® Surfactants give rich, creamy lathers that are richer in hard water.

Rule 3. Anionic surfactants aren't compatible with cationics.
HAMPOSYL® Anionic Surfactants work with cationics to maintain germ-killing power and hair conditioning.

Rule 4. Surfactants are used just for lowering the surface tension.
HAMPOSYL® Surfactants also act as corrosion inhibitors and under certain conditions will provide an antistatic, lubricating film to plastics, fibers and other surfaces.

Rule 5. Rich lathering means harshness to the skin and eyes.
HAMPOSYL® Surfactants lather beautifully and are mild, too.

Rule 6. Specialty surfactants never come in the form I need.
HAMPOSYL® Surfactants are available in a number of salt forms as well as the acid forms so handy for self-neutralization.

Rule 7. Specialty surfactants are too expensive to use.
HAMPOSYL® Surfactants are mid-priced and offer lots of formulation benefits.

Learn all the new rules for **HAMPOSYL** Surfactants today. Super foam, modest cost, unusual properties. Our **HAMPOSYL** brochure has 24 pages of ideas waiting for you.

GRACE

Organic Chemicals Division, W.R. Grace & Co.
Lexington, Massachusetts 02173
(617) 861-6600

CIRCLE 61 ON READER SERVICE CARD

Zeolites—sodium aluminosilicates—head the list of ion exchangers used in detergent formulations. Most that are used in detergents are of the "Type A" form. This form has the empirical formula, $Na_2O \cdot Al_2O_3 \cdot 2SiO_2 \cdot 4.5H_2O$, and a particle size in the range of $10\ \mu m$. These zeolites handle calcium ions well, but their pore size is too small to absorb hydrated magnesium ions. Being insoluble, their use is limited to powders.

The growth prospects for zeolites may be caught between conflicting actions. If phosphate bans increase, then more zeolites will be used in detergents as builders. But the shift toward liquid detergents will reduce growth of zeolites because of their insolublity. On balance, the outlook for zeolites' demand is expected to be one of slow growth, probably less than overall growth in detergents.

Sodium carbonate and sodium silicate often are combined as builders in detergents. The carbonate causes calcium and magnesium carbonates to precipitate. Unfortunately, despite addition of other materials, the precipitates cannot fully be prevented from redepositing on clothing where it leaves a "hard" feel to the fabric and possibly a grey color resulting from entrapped dirt. Sodium silicate provides alkalinity and buffering in the wash water, as does sodium carbonate. It also gives some corrosion protection for washing machine parts and acts as a processing aid in detergent manufacturing. With the advent of zeolites, use of these materials declined and renewed growth seems to be unlikely in the near term.

Bleaching materials rank another step down in importance in detergent formulations, but they either are a part of the detergent or are a separate addition to the washing program. These materials can be thought of as supplements to the surfactants that aid the physical methods of cleaning. Bleaches containing chlorine have been the standard for many years. Problems of residual chlorine and its odor have shifted some emphasis away from hypochlorites. Addition of dry hypochlorite bleaches to detergents generally is more expensive than is

Shell Oil technicians use automated equipment to test effectiveness of laundry detergents at firm's Westhollow Research Center in Houston

the use of a separate liquid bleach. But in some products, the convenience factor will justify the higher cost.

More recently, the peroxides (usually sodium perborate) have rapidly increased in demand from a relatively small base as a part of attempts by formulators of detergents to provide the convenience of single addition to the wash water. Hydrolysis of the perborate produces hydrogen peroxide, which does the oxidation. An activator frequently is added to the formulation to give good bleaching at low temperatures.

In the 1950s, peroxy carboxylic acids showed high bleaching performance. One of the best performers today is diperoxydodecanedioic acid, but its manufacture on a commercial scale was delayed by safety problems until Degussa and Henkel found a way in situ to desensitize the process. This material meets the requirements of good performance at low wash water temperatures.

The last category of detergent components is the auxiliary materials, the many examples of which are varied in both their composition and uses. Some are surfactants applied in specialized ways to act as antifoamers, fabric softeners, or antistatic agents. Other auxiliaries added to detergents are enzymes aimed at removing proteinaceous material, antiredeposition agents, optical brighteners, perfumes, dyes, filler, and formulation aids. If compared with the quantities of surfactants consumed, the quantities of these materials, except fillers, are tiny. However, most premium-quality detergent formulations for household use now contain most of these auxiliaries.

Enzymes were used in many U.S. formulations in the 1950s and 1960s, but were dropped for cost and performance reasons. Now, with the improvements in enzymes and in the ways of incorporating them in detergents, their use is increasing. Most enzymes have to work relatively rapidly to break a peptide or ester bond to be effective in removing proteinaceous stains.

Optical brighteners are members of several basic organic compound groups that have the ability to convert ultraviolet light into visible blue light. In effect, these materials do the same job that "bluing" agents (mostly ultramarine blue dyes) have been doing since the mid-19th century. Stilbene derivatives account for a large share of the commercially used optical brighteners, although many other compounds such as coumarin, pyrazoline, and quinolone derivatives are used.

Still more auxiliaries may be added to detergent formulations as a result of R&D efforts to provide more convenience and performance. Such additional materials and better surfactants will be needed if sellers are to gain share in the mature and nearly saturated market of detergents. □

Fourier Transform Mass Spectrometry
Evolution, Innovation, and Applications

Fourier Transform Mass Spectrometry (FTMS) is a rapidly growing technique that has the potential to become a valuable and versatile tool for both analytical and research applications. This new book brings together researchers who are investigating new applications of FTMS, as well as those who are developing instrumental advances in FTMS. You'll read reports on the current analytical capabilities of FTMS and projections on the future capabilities of this technique. You'll learn about a wide variety of applications, ranging from basic studies of dissociation of ions to the analysis of high molecular weight biopolymers. Topic highlights include:

- **Principles and Features of FTMS**
- **New Excitation and Detection Techniques**
- **Dual-Cell Fourier Transform Mass Spectrometer**
- **Instrumentation and Application in Analytical FTMS**
- **FTMS of Large Biomolecules**
- **Tandem FTMS of Large Molecules**
- **Laser Desorption-FTMS**
- **IR Multiphoton Dissociation of Laser-Desorbed Ions**
- **Photodissociation of Transition Metal Ions**
- **Negative Ion Processes**

Fourier Transform Mass Spectrometry offers an excellent general introduction to the technique as well as a summary of current applications. This book will be of value to chemists, biologists, physicists, and others interested in learning more about FTMS.

Michelle V. Buchanan, *Editor, Oak Ridge National Laboratory*

Developed from a symposium sponsored by the Division of Analytical Chemistry of the American Chemical Society

ACS Symposium Series No. 359
216 pages (1987) Clothbound
ISBN 0-8412-1441-7 LC 87-26107
US & Canada **$49.95** Export **$59.95**

Order from: American Chemical Society
Distribution Office Dept. 76
1155 Sixteenth St., N.W.
Washington, DC 20036
or CALL TOLL FREE

800-227-5558
and use your credit card!

FEBRUARY 1, 1988
CHEMICAL & ENGINEERING
NEWS

A1280-1
2/9/88

PRELIMINARY PROGRAM
3rd Chemical Congress of
North America, Toronto Page 33

High-Tech Ceramics

Composites promise
toughness for
structural applications
Page 7

0511179C098 9 K AR6605SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 5
CENEAR 66 (5) 1–64
ISSN 0009-2347

FEBRUARY 1, 1988

News of the Week

- **Sterling Drug accepts Eastman Kodak's $5.1 billion acquisition offer following aggressive bids by Hoffmann-LaRoche.** **Page 4**
- **New class of high-temperature superconductors that consist of relatively common, inexpensive elements could make future large-scale superconductivity applications more economical.** **Page 5**
- **All-protein, low-calorie fat substitute has been developed by NutraSweet Co., which plans to have the product ready to market in 12 to 18 months.** **Page 5**
- **Tests to identify alcoholics and people predisposed to alcoholism may result from discovery of certain biochemical markers.** **Page 6**
- **Alaska's North Shore is suffering alarming environmental problems as a result of oil and gas drilling, say the Natural Resources Defense Council and the National Wildlife Federation.** **Page 6**

Cover: 3M technologist uses propane torch to show heat resistance of strands of 3M's Nextel ceramic fiber, which can be added to ceramics to make tough composites

Letters 2

Concentrates
Business 13
Government 19
Science/Technology 23

The Departments
ACS News 31
People 32
Newscripts 64

Business

Polypropylene industry maps course for expansion with current and anticipated growth in mind. **Page 15**

Government

Superconducting Super Collider's immediate fate to be decided by this session of Congress, against fierce budgetary competition. **Page 20**

EPA Administrator Thomas sees final year in office as most challenging, has agenda set. **Page 22**

Science

BioDesign's software advances computer-aided molecular design, fully integrates graphics and molecular dynamics calculations. **Page 24**

U.S. and U.S.S.R. scientific communities restore and expand relations with agreements for extensive exchanges. **Page 25**

Education

Increase of foreign-born engineers working and studying in the U.S. is focus of NRC committee report. **Page 27**

Technology

Automated instrumentation for measuring landfill gases escaping from solid waste disposal sites is introduced by Varian Associates. **Page 28**

Preliminary Program

Preliminary program of 3rd Chemical Congress of North America and 195th ACS national meeting, to be held jointly in Toronto, includes list of symposia and advance registration coupon. **Page 33**

News Focus

High-tech ceramic composites, produced by incorporating ceramic fibers, whiskers, and particulates into ceramic matrices, have improved properties such as fracture resistance, strength, and high-temperature stability. **Page 7**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Patricia Oates (Administrative Assistant)
News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 63)

LETTERS

CHEMICAL SAFETY

Alkyl(thio)ethyl sulfides

SIR: A number of alkyl(thio)ethyl chloride ($RSCH_2CH_2Cl$) derivatives are commercially available and frequently synthesized in laboratories for use as radioprotective chemicals and for kinetic studies as model compounds. With gas chromatography/mass spectroscopy we detected trace amounts (0.05–0.1 mole %) of the chemical agent mustard $[S(CH_2CH_2Cl)_2]$ as a degradation product in the aged samples of methyl, ethyl, and phenyl derivatives. As high as 6 mole % mustard was found in the benzyl derivative, which decomposes more readily. All of the above compounds were acquired commercially and stored at ambient conditions for about one year. We would like to alert the chemical community of the increased toxicity of these compounds as they age.

The degradation process is believed to be initiated by the intramolecular, nucleophilic assistance of sulfur in the leaving of chlorine to form a reactive cyclic ethylene sulfonium ion, which is then quickly trapped by another molecule of the sulfide to form a relatively stable dimeric sulfonium chloride $[RS^+(CH_2CH_2Cl)(CH_2CH_2SR)Cl^-]$. With time, this compound slowly transforms to a number of secondary cations through further nucleophilic substitution reactions at the three electron-deficient carbon atoms adjacent to the S^+. This includes the formation of the $RS^+(CH_2CH_2Cl)_2$ cation, which decomposes to mustard (and RCl) as detected by GC/MS.

Mustard is a vesicant and can be contaminated by oxidation with bleach or peroxide solutions.

Yu-Chu Yang
Dennis K. Rohrbaugh
J. Richard Ward
U.S. Army Chemical Research
Development & Engineering Center
Aberdeen Proving Ground, Md.

Shock-sensitive salt

SIR: Dow Chemical Co. has found that the water-insoluble salt formed from mixing aqueous solutions of the polymerization initiators sodium persulfate and 2,2′-azobis (2-amidinopropane) hydrochloride is shock sensitive. The degree of shock sensitivity varies with moisture content, being greater at lower moisture levels, and is similar to that of lead azide.

Extreme measures should be taken to prevent aqueous solutions of these commercially available polymerization initiators from coming into contact with each other external to the polymerization environment.

D. A. Rausch
Corporate Safety and Loss Prevention
Dow Chemical

Chemical engineering

SIR: I have comments regarding two items in the Nov. 30, 1987, issue of C&EN.

First, the major article summarizing the National Research Council's report on chemical engineering's frontiers is very timely in at least two respects. One deals with the opportunities for persons with a chemical engineering background in materials science and engineering. It has been evident to me for some time that chemical engineers are perhaps even better qualified for materials processing research, development, and production roles than the typical materials engineer. That advantage is due to the generally higher level of computational skills possessed by most chemical engineers. It is quite apparent that materials science and engineering is headed for a more computational future. For example, the work done by people like professors Szekely at Massachusetts Institute of Technology and Brimacombe at British Columbia on process simulation is worth noting. If only the chemical engineers had a bit more experience in mechanical behavior.

The other timely feature of the article on chemical engineers is their likely pivotal role in resource and waste management. Their technical qualifications are clearly suited to the problems of analytical measurement and process control that underlie existing and developing practices in these technologies. However, I'm not sure that they will have been exposed to the philosophies that distinguish between short-term and long-term solutions to such problems: e.g., the considerations presented by Hirschhorn (*Pollution Engineering*, November 1987, page 62).

The second item of the Nov. 30 issue

Strong Demand for Polypropylene Spurs Expansion Plans

Global growth of 10% over past decade has pushed plants to limit; producers see brief excess capacity in 1990–91 but still high operating rates

Patricia L. Layman, C&EN London

With plants running at nearly 100% of effective capacity, and sometimes more, polypropylene producers around the world—and some companies not yet in the business—are building or making plans to build new production facilities. They have decided to up their stake in a "specialty shop" business characterized by many grades and types of polymer, and many different end uses.

Two central questions are raised by those decisions. Is the polypropylene industry embarking on a lemminglike course of collective madness, with gross overcapacity on the horizon? Or are corporate managers actually making wise decisions in building now for present and anticipated growth?

Naturally enough, producers are convinced that their plans are justified by the strength and growth of polypropylene markets. Yes, they say, there will be a brief period of overcapacity in about 1990 or 1991, when a large part of the new capacity goes on stream, and operating rates will dip down into the 85 to 90% range. But that's a far cry, they add, from the low points experienced in the years between 1978 and 1982, when operating rates dipped near 60%, never rising much above 75%.

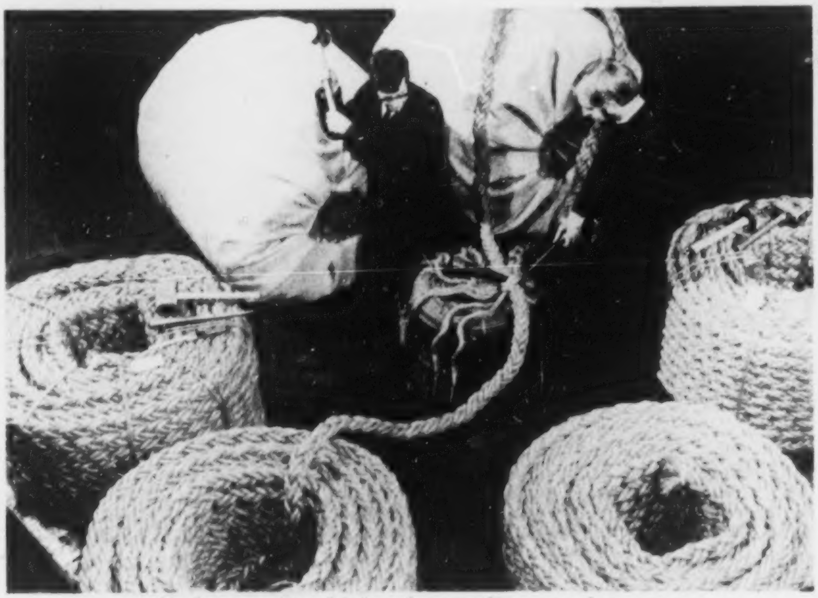
On the other hand, industry analysts have their reservations. Some see definite "lemming" signs. Others see grounds for caution, but overall, they believe, polypropylene producers may be justified in their expansionary plans.

Key to those plans are the impressive growth rates registered by polypropylene over the past decade. West German producer Hoechst calculates that worldwide demand from 1976 to 1986 grew an average 10.6%. Dutch producer DSM pegs global polypropylene demand growth between 1982 and 1987 at 8% per year. For Western Europe, in particular, growth has been even better: 11.4% per year between 1976 and 1986, according to Hoechst—more than double growth in demand for high-density polyethylene at 5.1%.

According to Gerald W. Pearson, vice president for plastics for Dow Chemical, speaking at a European Chemical Marketing Research Association (ECMRA) meeting in Barcelona last November, by 1995 polypropylene will account for 17% of global plastics consumption of 76 million metric tons. That share is up from 15% of 52 million metric tons in 1985.

With that kind of growth, marketers say, it is no wonder producers are busy working on expansion plans, because capacity increases have not kept pace with growth. In 1987, production, which had been edging up toward plant capacities, actually overtook capacity. As a result, marketers have been scrambling to supply customers, and, in turn, customers have been whittling down stocks. As one producer puts it, "All the plants are stretched out like elastic bands."

In some respects, polypropylene is just catching up with the other major polymers. With growth coming both from increasing consumption in present applications and in new substitutions, the real innovative potential for polypropylene was discovered relatively recently, considering how old the product is (the


Shell photo

Workmen splice ship's polypropylene mooring rope original patents date back to the early 1950s). The innovations have come both in replacing natural materials, such as raffia and jute fibers, and metals, woods, and paper, and in replacing other polymers, particularly those more expensive than polypropylene, such as polyamides and acrylonitrile-butadiene-styrene.

Some of the replacement of other polymers has been in fibers—polyester, in the raffia sector, for example. But the big opportunities really came with the advent of the Arab oil crisis, when the need for materials that could reduce vehicle weight to cut fuel consumption became crucial.

After autos, other markets began opening up to polypropylene. Thermoforming of food packaging—yogurt and margarine cups, for example—has become a major market for the polymer. Other packaging applications are important for polypropylene film. Uses in textiles—in disposable nonwovens, for instance, and in industrial fabrics—also have increased. Growth has been for the sake of its intrinsic qualities, and also for substitutions.

It's the continuing substitutions and diversity of markets that encourage marketers preparing their forecasts. "Look at polyvinyl chloride," says one supplier, "70% of it goes into construction. Most acrylonitrile goes into acrylic fibers. Polypropylene has all sorts of various uses." That factor, the supplier believes, helps shield polypropylene from the vagaries of economic ups and downs.

Additionally, "The growth rate in double digits over the past years has been because substitution has gone up tremendously. The price of polyolefins has gone down, so that now, polypropylene is a cheap product in the technical sense—the ratio of price to performance is very good, so people try to substitute it for other materials where they can."

Other growth is coming from developing countries. Says one marketer, "Polypropylene goes very well with developing countries, and as their standard of living increases, consumption of polypropylene will increase."

China, with its huge population, is one of the largest potential mar-

Himont dominates technology and industry

Currently, the polypropylene industry is dominated by Himont, formed in 1983 as a joint venture between Hercules and Montedison, and now owned 80% by Montedison and 20% publicly held. The venture joined Hercules' strong marketing organization and Montedison's technological and production expertise. It also yielded an operation that now accounts for nearly one fifth the world's polypropylene production.

Himont also has embarked on an aggressive campaign to license its technology, originally developed by Montedison and Mitsui in Japan but considerably broadened and improved by Himont. The company licensed 16 customers in 1987; its licensees currently account for roughly 50% of world capacity.

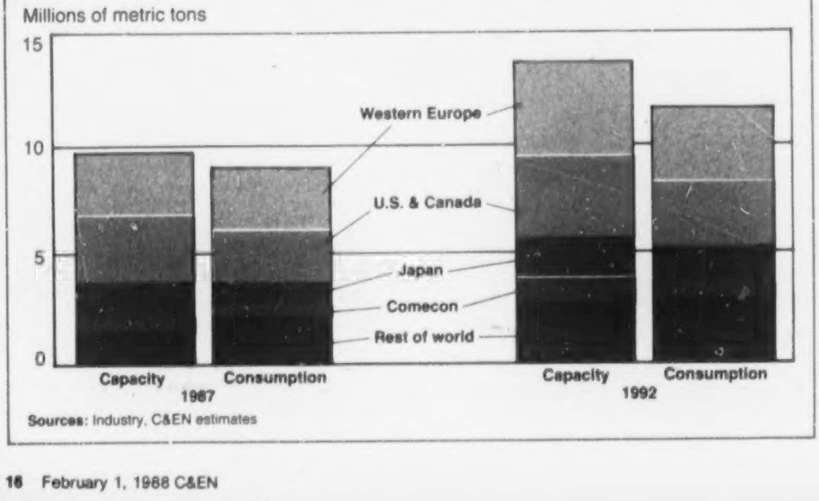
Probably the next most widely based technology is BASF's. Its technology will account for about 10% of world capacity currently in place and being installed between now and 1992. BASF's position was boosted by the formation of a tripartite agreement in October 1987 between it, ICI, and National Distillers & Chemical (now Quantum Chemical) in the U.S. to cooperate on research and development and to share process improvements.

Other major processes for license include the "super high activity" process of Shell in the U.K. and the U.S. Shell has linked up with Union Carbide in a process derived from Carbide's Unipol process for polyethylene. El Paso Products in Bayport, Tex., licenses Carbide's process; Solvay in Belgium has its own process; and DSM in the Netherlands has yet another. Virtually all companies are working on catalyst systems, building on the new generations that have developed. Neste, for example, soon will start up a pilot plant in Finland based on its own know-how, to help work on its own technology.

All the new technologies feature what Chem Systems consultant David F. Oxley terms "third-generation, high-yield catalysts," and his predictions as to future growth and capacities assume that by 1995 most producers will have them—if not the fourth-generation catalysts claimed by Himont. First-generation catalysts yielded about 1000 kg of polymer per kg of catalyst. Yields were boosted to 5000 to 10,000 kg per kg with second-generation formulations and about 30,000 kg per kg with fourth-generation catalysts.

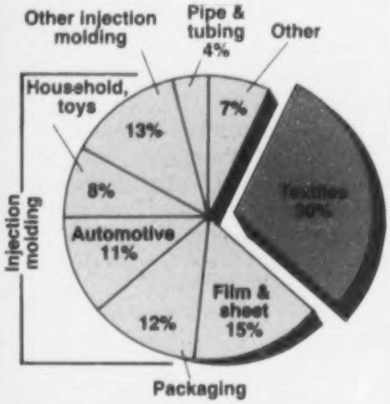
Catalyst technology is based on formulations of titanium supported on magnesium halide, an organometallic component, and a Lewis base as the electron donor. Each of them, in the variety of technologies, whether liquid slurry, gas phase, or liquid bulk, or modifications or combinations, will give roughly similar processing costs, Oxley believes. "The cost of polypropylene then will basically be the cost of propylene," he says.

Western Europe to lead global polypropylene growth



Sources: Industry, C&EN estimates

Textiles are largest single use in Europe



Total 1987 polypropylene demand = 2.63 million metric tons

Sources: Industry, C&EN estimates

kets. As with so many other things, polypropylene consumption—if increased by only a little bit per capita—could increase tremendously in total consumption, suppliers point out. China itself has a number of plans for polypropylene, as do other countries in the Far East. But U.S. and Western European producers feel that those regions will remain net importers well into the next decade. In Barcelona, Dow's Pearson told the ECMRA, for example, that by 1995, China would still be importing 390,000 metric tons per year of polypropylene.

Naturally, producers expect that polypropylene growth eventually will slow down. But at least one has said that it has already had to upgrade estimates for 1987 and 1988, because earlier forecasts were too conservative. Most companies have been predicting that growth in demand for polypropylene in industrial regions such as North America, Western Europe, and Japan will be slower than in the rest of the world, probably 4 to 5% per year, compared with 6 to 7% in the rest of the world. However, consumption actually grew throughout 1987 at a 14 to 15% clip.

Some analysts worry about basing plans for new capacity expansions on such growth rates, even the conservative forecasts. Says Morgan Stanley analyst Stuart Wamsley: "Although those companies that are moving ahead with investment in major new ... polypropylene ... plants may well reap considerable rewards if the world's economies continue to expand, there will be some very red faces, seriously depleted profit and loss accounts, and damaged balance sheets if a downturn does materialize." Much wiser, he argues, is a modest course of debottlenecking, or allowing capacity to creep up gradually.

On the other hand, other industry observers feel that the situation won't be that bad for polypropylene. Tony Church, chemicals specialist with analysts Wertheim Schroder & Co., concedes that "there is undoubtedly a concentration of new plants in late 1989," but he thinks that the scrapping of old facilities and delays in the startups of new plants will alleviate the impact of "bunching" new plants.

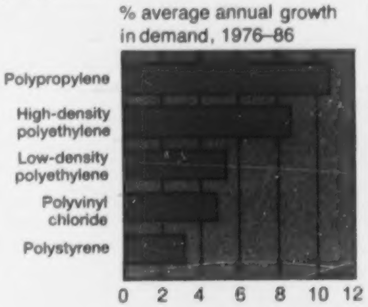
Moreover, demand for polypropylene on a global basis is growing faster than available supply, he points out. "An economic slowdown in late 1988 and new plants starting up in 1989 could put an end to the current tightness of supply, but we see no signs of a major slowdown for at least nine to 12 months. On a longer-term basis, our forecasts suggest that the current industry capacity increase is not excessive."

By and large, if growth matches the predicted rates, any overcapacity that develops from 1990 to 1992 will be short-lived, relatively painlessly absorbed by the markets. However, the future global economy worries some more conservative producers; they fret over the possibility of slowed growth and outright recession.

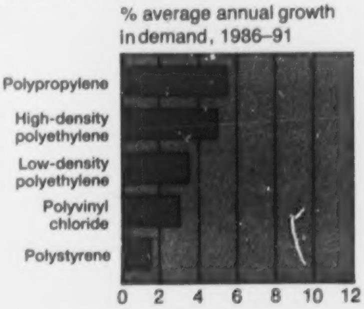
Given the gamesmanship of the business, it's difficult to predict how the industry might weather some of the possibilities. For instance, at least some of the announced planned capacity probably will never be built. In many respects it is like a poker game: If one company announces a large enough new plant, will that spook others into pulling back on their plans? Or can one company negotiate more favorable contracts from other suppliers in return for not building additional capacity? For example, Belgian carpetmaker Beaulieu has announced that it will build a 120,000 metric ton-per-year polypropylene plant in Dunkirk, France, to start up in 1989 to ensure its supply of polypropylene fiber for carpetbacking. Industry observers were not convinced that Beaulieu actually would build its plant—it might have been a bid to help it with favorable long-term contracts for its supply. However, Beaulieu in December took a license from Union Carbide to build its plant, so its plan is definite.

Alternatively, a producer might ask, if it makes dire-enough predictions, whether that will convince others not to plan expansions. At least one producer, following expansion announcements from its competitors, has said, "In the field of polypropylene, the lemmings are already gathering, and some are looking over the cliff. If you add up all the information, you can get afraid of what is going to happen." That may be true, but then again, that producer also plans significant expansions.

Polypropylene tops other polymers in growth...



... and will continue to, but at a slower rate



Source: Hoechst A.G.

Four companies account for a fourth of worldwide capacity

Thousands of metric tons	Nameplate capacity in 1988[a]	Planned expansions to 1995
Himont (U.S.)[b]	1800	150
Shell (U.K./Netherlands)	875	120
Amoco (U.S.)	570	
Hoechst (West Germany)	515	110
25% of total world capacity in 1988[b]		
Exxon (U.S.)	430	70
Fina (U.S.)	380	
ICI (U.K.)	300	100
Appryl (France)	265	
Neste (Finland)	240	200
DeMV (Austria)	200	120
50% of world capacity		
Phillips (U.S.)	190	
El Paso (U.S.)	165	135
Soltex (U.S.)	135	95
BASF (West Germany)	135	150
Solvay (Belgium)	130	
DSM (Netherlands)	120	
Huels (West Germany)	120	
Montefina (Italy)	120	
60% of world capacity		

Note: All locations indicate headquarters, not necessarily plant sites. [a] Design capacity based on announcements through December 1987, with no allowances made for scrapping of old capacity unless companies have announced specific plans to scrap. [b] 11.1 million metric tons. **Source:** Wertheim Schroder & Co., London

One of the natural limits to any polypropylene expansion will be feedstock availability, a point virtually all producers and analysts agree on. Increasingly, they predict, if a producer has no internal or well-tied source of propylene, it will be difficult to expand polypropylene production, or perhaps even keep up present levels. For example, a world-scale plant is now considered 120,000 metric tons per year. "You wouldn't do an expansion unless it was that amount, and to contract for that much propylene will be difficult to do," says one supplier. "If you are not integrated into propylene, it will get more and more difficult."

Propylene supply is not a foolproof limit, however. For example, some of the projects under way or under consideration will depend on dehydrogenation of propane. Saudi Basic Industries Corp. (SABIC), for one, is currently conducting feasibility studies on polypropylene to be completed later this year. Although the company declines to comment before the studies are completed, it is examining plans for a joint venture, probably with Neste of Finland, to produce 200,000 to 250,000 metric tons of propylene, with either a portion or all converted into polypropylene. The propylene production would come through propane dehydrogenation.

Some suppliers feel that SABIC is waiting to see what happens with a new polypropylene project under way in Thailand—one of the first of its kind. Dehydrogenation propylene will feed a 100,000 metric ton-per-year polypropylene plant. Points out one supplier, "No one really has any commercial experience with this technology yet. Everyone is waiting to see what happens."

But clearly, the idea of propane dehydrogenation has attractions. The recently announced joint venture between Himont and Statoil of Norway for a polypropylene plant in Belgium has as one option feedstocks of dehydrogenation propylene—a fully integrated facility, starting with propane, going through dehydrogenation to propylene, and on to polypropylene. In this case, the joint venture was particularly well suited for Himont, with no secure source of feedstock for a new plant in Europe. And it helps move the company away from the industry's historical dependence on feedstock supply from ethylene crackers or refineries. The linkup also suits Statoil, which will have abundant quantities of propane from its North Sea operations via a refinery in Norway, which is due on stream by 1990.

The other limit to overcapacity in the industry will be the relative abundance of old-technology plants. These can continue to be run profitably when the market is tight and selling prices high. But if there is significant overcapacity, and prices and margins begin slipping, older, more expensive technology is more and more costly to operate. Hence, those conditions might provide an incentive for companies who had procrastinated in scrapping to finally do so.

According to one industry source, an analysis of aging polypropylene capacity would suggest that at least 50% of production is in plants more than 10 years old. "In a technology moving as rapidly as polypropylene, a 10-year-old plant is no longer competitive, either economically or technologically," he contends. "These plants are viable now only because of the tight market, but they are the marginal plants. We expect something similar to what happened as linear low-density polyethylene has come in: Old-plant producers will drop out."

Perhaps even more than with polyethylene, polypropylene producers have been reluctant in the past to commit to new plants because of the continuing debate over technology. Says one supplier, "There has been a technological revolution, and those wanting to expand have been very careful to stay on the knife edge of technology."

"Before 1983 was a very bad time for polypropylene," another supplier says. "Since about 1982, capacity utilization has improved from about 65%. But when people saw capacity utilization coming up, they didn't have the confidence to expand. It has been drummed into our heads that there are five-year cycles, and we didn't want to go crazy. The world never stopped building polypropylene plants, but we didn't have the confidence to build them fast enough." Nor did people expect growth rates to continue as strongly as they have, this supplier adds.

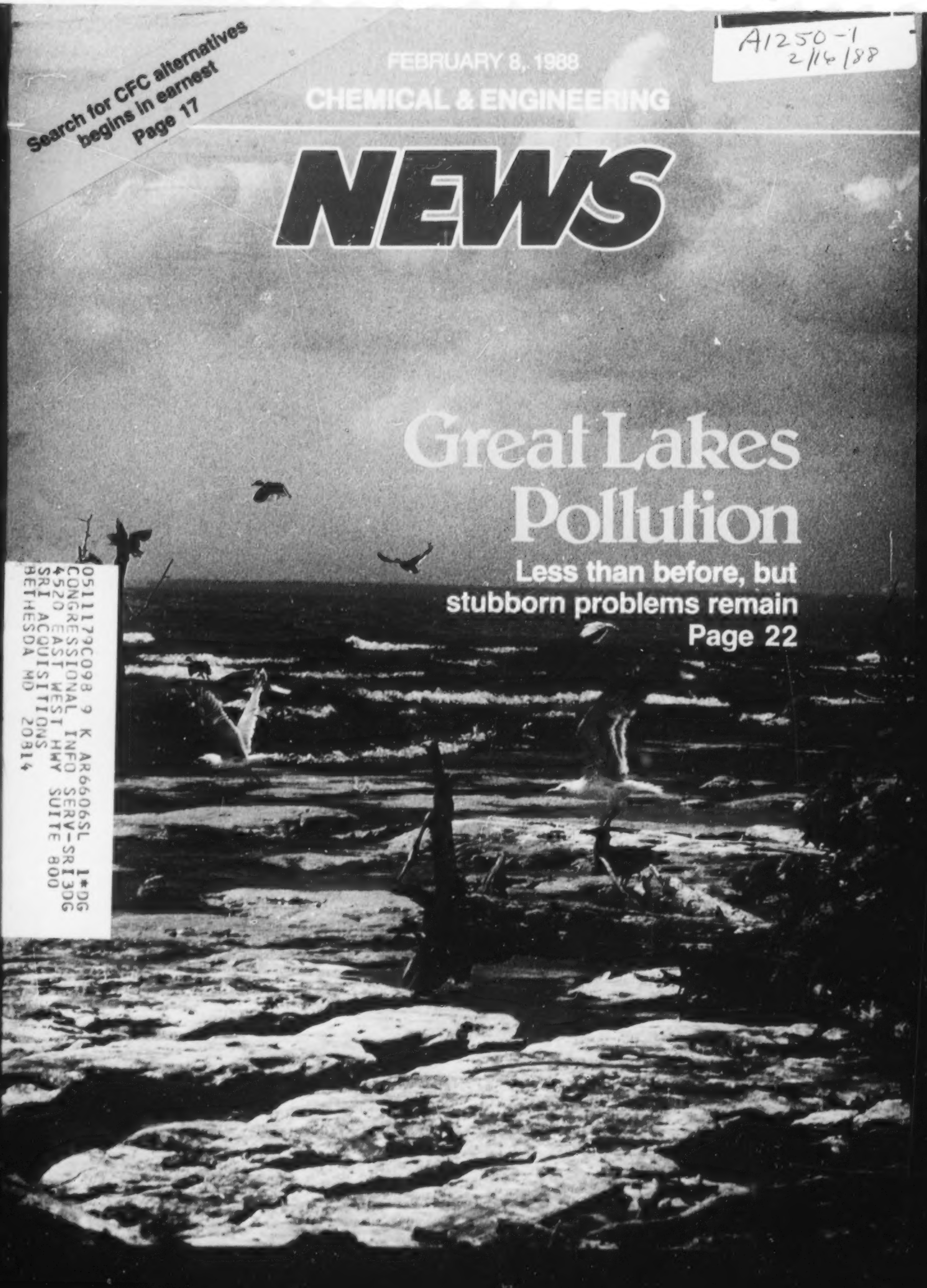
"We all were asking, how much of that was real growth? How much was pipeline filling? How much was substitution? But when the growth lasts this long," one marketer argues, "it has reached a steady state. It is not just pipeline filling, but true growth in demand. And in any growing demand, you must have a growth in stock."

Who will be growing, then? The majors—the top two, Himont and Shell certainly, and the next level, as serious contenders. But with world scale at 120,000 metric tons per year, a number of producers now are almost in what one producer terms a "double or quit situation—they are playing games now." □

A1250-1
2/16/88

FEBRUARY 8, 1988

CHEMICAL & ENGINEERING NEWS



Search for CFC alternatives begins in earnest
Page 17

Great Lakes Pollution

Less than before, but stubborn problems remain
Page 22

0511179C098 9 K AR6606SL 1*DG
CONGRESSIONAL INFO SERV-SRI3DG
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 6
CENEAR 66 (6) 1-56
ISSN 0009-2347

February 8, 1988

News of the Week

- **China announces that National Chemicals Import & Export Corp. will go multinational and that it plans to open Chinese borders to broader foreign trade and investment. Page 4**
- **Shell Oil Co. and the Army have agreed to share costs of cleanup of federal arsenal property in Colorado where more than 140 specific hazardous waste sites are thought to be. Page 5**
- **Although chemical warfare disarmament talks have resumed in Geneva, prospects for a treaty are dim in face of the many contentious issues still to be resolved. Page 5**
- **Du Pont begins production of test lots of fluorocarbon-134a, a potential substitute for ozone-depleting chlorofluorocarbons. Page 6**
- **New fat-dissolving enzyme for detergents will be produced by Novo Industri, a Danish bioproducts company, at manufacturing facility in Hokkaido, Japan. Page 6**

Cover: Spider Island in Lake Michigan. Photo by Timothy J. Kubiak, U.S. Fish & Wildlife Service

Letters 2

Concentrates

Business 7
Government 13
Science/Technology 16

The Departments

Meetings 41
Newscripts 56

Business

Hoechst Celanese's blast-destroyed Pampa, Tex., acetic acid plant is being rebuilt, thanks to a strong market for the chemical and support from the local community. **Page 9**

American Cyanamid is manufacturing isocyanates in its new world-scale production facility in Willow Island, W.Va. **Page 11**

European chemical industry could see slowdown in growth this year compared with 1987. **Page 12**

Government

Reagan sets legislative agenda for 1988, including a permanent R&D tax credit and increased spending for AIDS research. **Page 14**

Acid rain accord has U.S. and Canada at odds over proposed cuts in sulfur dioxide emissions. **Page 15**

Technology

Chlorofluorocarbon producers scramble to develop alternatives to CFCs to meet deadlines Montreal protocol would impose. **Page 17**

Special Report

Although much progress has been made since the Great Lakes cleanup effort was initiated in 1972, the effects that persistent contaminants may have on aquatic life, fish-eating birds, and humans are cause for concern. Page 22

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin

Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski

Staff Editor: Ernest L. Carpenter

Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer

Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer

Service Departments Editor: Dolores Miner

Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)

Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos

Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

Importance of safety

SIR: Recently, while shopping for a chemistry set for my niece's Christmas present, I had the opportunity to examine several sets produced by two companies: Educational Design Inc. and Natural Science Industries. I was appalled to find cover illustrations/photographs on the packages of these sets featuring bright-eyed and excited males (no females) with no eye safety on. Although one of the sets at least showed a picture of its contents, which included safety glasses, it still showed the young man closely examining an experiment without eye protection. It is disturbing to see such images displayed that could clearly mislead the consumers of these sets as to the importance of safety considerations when using this equipment.

I am writing independently to the manufacturers to complain and urge them to remedy this situation. I would urge ACS membership, and indeed the leadership, to apply the appropriate pressure to change these companies' marketing and displays. I believe this is a large market where safety is of paramount concern.

Joseph A. Gardella Jr.
Associate Professor of Chemistry
Associate Director, Surface Science Center
State University of New York, Buffalo

Learning to love metric

SIR: Hugh W. Thompson (C&EN, Jan. 4, page 4) makes an assumption that is totally unsupported by the data. He believes that the use of accepted metric terms confuses the public and somehow affects the ability of scientists to communicate with the nonscientific community. He underestimates the public's ability to handle terms such as hertz and Celsius [the other names he mentions, torr and dalton, are not accepted nomenclature in the International System of Units (SI) as set forth in ASTM Publication E 380-86, "Standard for Metric Practice"].

The public certainly has had no difficultly comprehending terms such as volt, faraday, watt, or Fahrenheit, so why the fuss about other terms of measurement that take their names from those scientists who contributed to that field of science?

The SI Metric System of Measurement is a rational, coherent system, based on the well-known metric (decimal) system, and is in exclusive use in almost all countries in the world, with the notable exception of the U.S. In an international market, where more and more metrically designed and manufactured goods are being imported into and exported out of the U.S., it is only a matter of time before SI metric becomes the accepted system of measurement here. And at that time, the scientific and nonscientific public will have little difficulty in learning the new terms and names, especially since they have been exposed to metric goods for many years (camera film, skis, automobiles, soft-drink bottles, etc.).

The fact that the names of many of the measurement units happen to honor scientists of the past will then surely heighten the public's enthusiasm, understanding, and willingness to accept this novel, easy-to-use and easy-to-understand system.

Jack G. Lowenstein
Director of Administration and
Metric Coordinator, Chemical Groups
FMC Corp., Princeton, N.J.

Individual research grants

SIR: With due respect to our colleagues in the arts, the undeniably most significant contribution of the U.S. to the human civilization has been in the area of science. It resulted from the work of many scientists who have found the optimal conditions for the expression of their creativity in this country. In turn, it has been one of the dominating factors behind its present economical and political strength.

It is not necessary to go far back in history to see that the decline of any society has been always preceded by the decline of its cultural values. This point seems to be well understood in many countries of Western Europe and in Japan in particular. The broad support for individual research in those countries is becoming the envy of many U.S. scientists. Even a casual conversation with U.S. colleagues leaves no doubt that it is now more difficult than ever to obtain individual research support from federal sources.

I would like to voice my concern about the apparent imbalance between

Correction

- Jan. 11, page 5: The investment banking firm that assisted Hoffmann-La Roche in its bid for Sterling Drug is Morgan Guaranty, not Morgan Stanley.

CHINA'S REFORMS: Chemical firm to go multinational

As part of its far-reaching economic and political restructuring—aimed at quadrupling industrial and agricultural output between 1980 and 2000—China has just announced two major steps opening the country to wider foreign trade and investment.

In the first development, China's National Chemicals Import & Export Corp. (Sinochem) will go multinational and diversify. In the second, Communist party leader Zhao Ziyang has announced an export-oriented economic plan calling for greater links with foreign investors and world markets and for mobilization of science and technology to boost production.

Sinochem was founded in 1950 as an import-export business for chemicals and petroleum. It is China's largest trading company, doing \$8.3 billion in business in 1987, up \$1.6 billion from 1986.

However, under China's "open door" policy more and more Chinese companies are importing and exporting. Rather than just compete with them, says general manager Zheng Dunxun, Sinochem will "explore new channels for the country to gain foreign currency. We will make efforts to promote economic efficiency and develop diverse operations, and eventually turn Sinochem into a new kind of socialist transnational corporation."

The firm will become a comprehensive economic entity, handling not only imports and exports but production, finance, transport, insurance, leasing, advertising, real estate, and services. In the future it will turn over only part of its annual profit to the state, keeping the rest for further development.

It also will diversify into other oil- and chemical-related businesses. With more autonomy, it can seek foreign funds, launch joint ventures and coproduction agreements, and develop barter trade and other forms of countertrade. In addition, it can process materials provided by customers, act as agent for others, and import and export chemical technology and equipment.

U.S. chemical exports to China are triple imports

\$ Millions[a]	Exports[b]	Imports[c]
ALL CHEMICALS	**\$593**	**\$180**
Fertilizers[d]	197	0.03
Plastics, resins	163	4
Organic chemicals	117	36
Inorganic chemicals	63	38
Pharmaceuticals[e]	24	28
Essential oils, perfumes	3	14
Dyes[f]	2	6
Explosives, pyrotechnics	0.1	41
Others	24	14
ALL COMMODITIES	**\$2743**	**\$5891**

a For 10 months in 1987. b Free alongside ship values. c Includes cost, insurance, and freight. d Manufactured. e Includes medicinals. f Includes tanning, coloring products. Source: Department of Commerce

The company already has initiated such activities. It has moved into oil refining, set up a petroleum station in Singapore, and has plans to build filling stations in Europe. It has a shipping joint venture, and it recently expanded barter and entrepôt trade in petroleum, chemical fertilizers, and plastics. It already has 40 branches in China and 23 overseas subsidiaries, offices, and agencies.

Meanwhile, Zhao has set out an economic reform strategy emphasizing accelerated export development in China's coastal provinces and calling for more foreign investments, technology, management expertise, and technical talent to advance production. Chinese leaders have been greatly impressed by the rapid, export-led development of what they call the "four dragons" of Asia—South Korea, Taiwan, Hong Kong, and Singapore.

Industries in coastal areas would import raw and semifinished materials from abroad, process them to increase their value, and then re-export them, Zhao says. Attraction of foreign investment is a top priority: "When foreign businessmen have shared interests with us, they will pay attention to product quality, technological improvement, management, and marketing; and this is in our interest."

Improved management is another top priority. "For a very long time," Zhao notes, "the working discipline in many of our plants has been lax, and financial and material management chaotic. In short, outdated management has been a very common phenomenon in our enterprises and the waste caused in this regard is shocking." In the trade area, "Foreign trade enterprises should have full authority over management and full responsibility for profits and losses."

One way of speeding up management reform, Zhao adds, is to permit foreign businessmen directly to administer Sino-foreign joint ventures as well as enterprises they wholly own in China "in accordance with international norms. We should create an environment in which foreign entrepreneurs can do business just as they would in most other countries in the world. The main criterion for judging whether an investment climate is good is to see whether it can produce profits." And he terms "mistaken" the previous Chinese belief that "letting foreign businessmen administer enterprises meant losing our sovereignty."

Zhao notes that China has a stronger scientific and technical work force than do most developing countries, but so far institutional and policy factors have limited its contribution to China's development efforts. Therefore, he urges mobilization of scientists and technicians to participate in international exchanges and competition. He advocates "hooking up research units' benefits with their research results." Thus, "The better their results and the more these results are needed by society, the greater the research units will be rewarded." He doesn't worry that this will encourage only short-term research: China currently has "far too few" projects that can produce short-term results.

Moreover, the Chinese leader would encourage scientists to become entrepreneurs: "We should let scientific and technical personnel operate enterprises directly—especially the technology-intensive industries." And he advocates setting up knowledge-intensive enterprises close to research centers or schools.

China is already doing well at increasing its exports to the U.S. Clayton K. Yeutter, the U.S. trade representative, was in Beijing last week to sign a pact cutting China to just 3% annual growth in textile sales to the U.S. for the next four years, and to discuss reduction of Chinese trade barriers. Through October last year, the U.S. imported $5.9 billion in Chinese goods and exported just $2.7 billion. Chemicals are a bright spot, however, with U.S. exports more than triple imports.

Richard Seltzer, Washington

Shell, Army to clean up Colorado arsenal site

Under a federal consent decree, the Army and Shell Oil Co. have agreed to share the costs of cleaning up toxic chemical wastes at the Rocky Mountain Arsenal in Colorado. The cost of the operation at the 27-square-mile site could be more than $1 billion, making this the most expensive cleanup ever negotiated.

The Army manufactured chemical and incendiary weapons during World War II at the arsenal and made nerve gas there during the Korean War. Shell Oil came onto the site in 1952 when it bought an existing company that was producing pesticides there. Shell continued the operation until 1982. More than 140 hazardous waste sites are thought to be on the arsenal property.

The agreement settles a 1983 lawsuit against Shell by the Justice Department asking reimbursement for government costs already incurred at the site. "The consent decree is the result of two years of intensive negotiations," says acting assistant attorney general Roger J. Marzulla. "It is important to stress the cooperative efforts by the Army, Shell, and other federal agencies that led to this proposal."

Although the decree sets out no specific cleanup schedule, the current goal for completion of work is the year 2000. R. G. Dillard, Shell's vice president for public affairs, says that the decree does not specify any particular cleanup plan. "Future studies will determine the scope of the remedial plan," he says, "but the decree does provide for some very significant work to commence before the final plan is selected."

The total cost of this enormous cleanup will be shared by Shell and the Army under a formula contained in the decree. For the first $500 million, each will pay half the expense. For costs between $500 million and $700 million, Shell will contribute 35%, and for expenses in excess of $700 million, Shell will pay 20%.

The formula is based on several factors, including the relative quantities of contaminants disposed of or released by each party and the degree of toxicity of those wastes. In addition, the consent decree specifies 13 remedial cleanup projects that the Army and Shell are supposed to complete before development of final cleanup plans. The cleanup plan for the arsenal's soils and water is to be completed by 1992, and plans for cleaning up groundwater off the site a year later.

David Hanson, Washington

Progress on chemical warfare treaty slows

Chemical warfare disarmament talks have resumed in Geneva at the Conference on Disarmament. The optimistic glow of last year's progress toward totally eliminating chemical weapons is fading in the face of many contentious issues remaining to be resolved.

The pace of the talks quickened last year because the Soviet Union made several spectacular concessions. "Major east-west or U.S.-U.S.S.R. differences, particularly on verification, were resolved," says Elisa D. Harris, visiting fellow at the Royal United Services Institute in London. But this year's session will focus on more politically difficult north-south issues. Among these are "who will pay for implementing the convention, and whether technical assistance will be given to developing countries as a quid pro quo for their participation in it," she adds.

Some supranational organization will have to be established to ensure compliance with a chemical warfare treaty. But its size, organizational structure, and operational costs need to be resolved.

Nonaligned nations with no chemical weapons are reluctant to become parties to a treaty that would require a costly organization. They would, however, as enticement to enter into the accord, welcome economic assistance to develop their own chemical industries. The U.S.

U.S. Army photo

Ban would eliminate need for training in protective gear such as this

Search Intensifies for Alternatives To Ozone-Depleting Halocarbons

Anticipating ratification of Montreal protocol, producers of chlorofluorocarbons are striving to develop substitutes for fully halogenated CFCs

Pamela S. Zurer, C&EN Washington

"What grand opportunities there are for the businesses that come up with solutions first," Environmental Protection Agency economist Stephen Anderson recently told an international conference on substitutes and alternatives to ozone-depleting halocarbons. "It's a billion-dollar opportunity," he said. "Best of luck in earning large profits while protecting stratospheric ozone."

Anderson's exuberant attitude was decidedly more upbeat than that of most of his audience—more than 500 scientists, engineers, and business executives from industries that produce and use chlorofluorocarbons (CFCs) and halons (fluorocarbons that contain bromine atoms). They gathered in Washington, D.C., last month to exchange information and ideas among themselves and with researchers and regulators from government. Although few are as spirited as Anderson, they are turning to meet the formidable challenges that lie ahead with determination.

The force behind those challenges and the impetus for the conference—sponsored by EPA, Environment Canada, and the Conservation Foundation—is the Montreal Protocol on Substances That Deplete the Ozone Layer. That international agreement will freeze consumption of CFCs at 1986 levels on July 1, 1989. Later cuts in output will reduce CFC consumption first by 20% by mid-1993, then by an additional 30% by mid-1998. Consumption of halons is to be frozen at 1986 levels.

Although signed by the U.S., the European Community, and 23 other nations last September, the Montreal protocol will go into effect on Jan. 1, 1989, only if it has been ratified by at least 11 countries accounting for two thirds of world consumption. None have yet done so, but chances are excellent that the agreement will be quickly ratified. In the meantime, neither the U.S. government nor industry is standing still waiting for the other shoe to drop.

EPA has already proposed regulations, expected to go into effect Aug. 1, that will control halocarbon output in the U.S. through a system of production quotas. Companies that made CFCs and halons in 1986 will be allocated "rights" to produce the chemicals based on the firm's share of total 1986 output. Market forces will control which users get the reduced supplies available—and at what price.

Producers of CFCs are scrambling to develop alternatives to fully halogenated halocarbons, particularly CFC-11 ($CFCl_3$) and CFC-12 (CF_2Cl_2). These two compounds, the largest-volume CFCs, are heavily used in refrigeration and air-conditioning, and as blowing agents for producing polymer foams.

"The search for CFC alternatives

"This isn't going to do the old ozone layer any good, that's for sure."

Drawing by Ross; © 1987, The New Yorker Magazine Inc.

began in the mid-70s," notes Joseph M. Steed, environmental manager for Du Pont's Freon products division. Spurred by EPA's ban on the use of CFCs in most aerosol products, the major producing firms began to look at the chemical and physical properties and toxicity of likely alternatives.

After a certain point, however, the companies declined to invest the resources necessary to proceed to plant development and long-term toxicity tests. "The customer demand wasn't there 10 years ago," says S. Robert Orfeo, senior research associate with Allied-Signal.

But now the Montreal protocol is providing the incentive for CFC producers to move quickly into alternatives. "It will be difficult to provide the needed materials in time," Steed says, citing an estimated five to seven years before toxicity testing and design and construction of new plants can be completed.

The chemical candidates receiving the most attention as likely substitutes are fluorocarbons-123 ($CHCl_2CF_3$), -134a (CH_2FCF_3), and -141b (CH_3CCl_2F). The physical properties of these compounds are similar enough to CFC-11 and CFC-12 so that they could be substituted in certain uses without major redesign or refitting of existing equipment. None showed any major problems in acute toxicity tests. All three carry hydrogen atoms that make them susceptible to degradation in the lower regions of the atmosphere—unlike the fully halogenated CFCs whose long half-lives let them survive until they reach the stratospheric ozone layer.

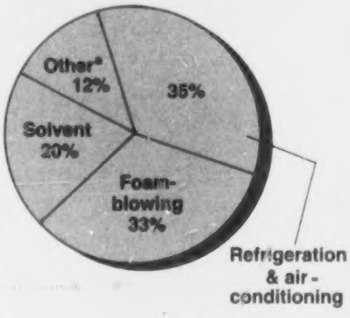
Two of these possible substitutes, 123 and 134a, will undergo long-term inhalation toxicity tests in a multimillion-dollar cooperative program set up by 13 CFC producers from the U.S., Europe, and Japan (C&EN, Jan. 11, page 6). This unprecedented collaboration is aimed at avoiding duplication of effort and shortening the time required to complete the tests.

The failure to include 141b in the toxicity testing program raised some eyebrows at last month's conference. Pennwalt Corp. is pushing 141b as "the blowing agent of the future." The firm predicts 141b will cost less than 123, the other viable candidate for a foam-blowing substitute. Interestingly, Pennwalt is not among the U.S. CFC producers that joined the cooperative testing program.

"We figure we can handle two compounds in the time-frame established by the protocol," says Michael R. Harris, halocarbon development manager for ICI Americas, in explaining why 141b has not been included in the consortium's plans. "It's simply a matter of prioritization—we hope we've judged correctly."

Although there are only a limited number of chemical companies that produce CFCs and halons, EPA estimates there are 10,000 firms in the U.S. alone that use the compounds. The impact of the new restrictions will vary widely among user industries. Most will need to apply several different strategies—conservation, recycling, the use of substitutes, redesign, and retooling—in order to cope.

Cooling, foam-blowing are largest U.S. CFC uses



1985 total consumption = 610 million lb

[a] Includes aerosols, sterilization, food freezing, and other miscellaneous uses.
Source: Environmental Protection Agency

Eight halocarbons to be controlled under Montreal protocol

Substance	Ozone-depleting potential[a]	Atmospheric lifetime, years	Major uses
GROUP 1—Production cuts mandated			
$CFCl_3$ (CFC-11)	1.0	75	Flexible foam, rigid polyurethane foam, refrigeration, air-conditioning
CF_2Cl_2 (CFC-12)	1.0	111	Rigid polyurethane and rigid nonpolyurethane foam, refrigeration, air-conditioning, aerosols, sterilization, food-freezing
$C_2F_3Cl_3$ (CFC-113)	0.8	90	Solvent
$C_2F_4Cl_2$ (CFC-114)	1.0	185	Rigid nonurethane foam, refrigeration, air-conditioning
C_2F_5Cl (CFC-115)	0.6	380	Refrigeration, air-conditioning
GROUP 2—Production freeze mandated			
CF_2BrCl (Halon-1211)	3.0	25	Portable fire extinguishers
CF_3Br (Halon-1301)	10.0	110	Total flooding fire-extinguishing systems
$C_2F_4Br_2$ (Halon-2402)	b	na	Fire extinguishers

a Estimates depending on chlorine and bromine content and atmospheric lifetime. Potentials are set relative to CFC-11, which is assigned a value of 1.0. b To be determined. na = not available. **Source:** Environmental Protection Agency

The electronics industry, both in the U.S. and abroad, faces one of the toughest problems in adjusting to curtailed CFC production. The use of CFC-113 (CCl_2FCClF_2) as a solvent for cleaning electronic assemblies has been growing in the past few years at a double-digit rate.

"One of the biggest stumbling blocks in the negotiations for the Montreal protocol was how to handle CFC-113," says Eileen Claussen, director of program development in EPA's office of air and radiation. "Its use is projected to keep rising and it is the most difficult CFC to replace."

The low toxicity, nonflammability, and stability of CFC-113 make it a "wonder product for high technology," says Morris A. (Bud) Ward, director of environmental and occupational health for the American Electronics Association. "Over the past decade it's become the solvent of choice: The industry had been eager to get away from the environmental and toxicity problems associated with methylene chloride and trichloroethylene. We've been concerned that not much has been happening in terms of substitutes for 113."

Claussen and Ward, like many others at the conference, were extremely interested to hear that AT&T and Petroferm Inc., of Fernandina Beach, Fla., have developed a substitute for CFC-113 in certain electronics manufacturing processes. Indeed, a press conference to announce the development was jammed with more representatives of the electronics industry, regulatory agencies, and environmental groups than reporters.

The substitute cleaning agent is a biodegradable mixture of terpene hydrocarbons and surfactants known as Bioact EC-7, according to Petroferm's chief executive officer William R. Galloway Jr. "Extensive experience with AT&T and some experience with other manufacturers has clearly demonstrated that it cleans printed circuit boards as well [as], or better than, chlorofluorocarbons or chlorinated solvents," he says.

David R. Chittick, AT&T engineering vice president, says the Petroferm fomulation cleans soldering flux residues from electronic components, even from advanced surface-mount circuit boards, which are much more difficult to clean than older designs. AT&T, which used about 3 million lb of CFC-113 in 1986, expects to replace about one quarter of that usage with Bioact EC-7 during the next two years.

AT&T's Chittick points to circuit board that Bioact EC-7 will clean

C&EN staff photos

Harris: a matter of setting priorities

AT&T has tested the terpene solvent in three of its plants, using a new cleaning system designed by its scientists at Bell Labs. The firm says it will make its technology available to other manufacturers who wish to use it. Even counting the cost of replacing the cleaning machinery, Bioact EC-7 costs about the same as CFC-113, Chittick says, and may become cheaper as CFC costs rise under the restrictions of the Montreal protocol.

"The AT&T and Petroferm announcement is very encouraging news but it sounds too good to be true," Ward says. "We'll have to look at it with healthy skepticism. It's one piece of the puzzle in reducing CFC-113 use."

Another industry that will be hard hit by restrictions on CFC consumption is rigid insulating foam manufacturing. CFC-11 is used to blow polyisocyanurate and polyurethane foam insulation that is widely used in new construction and remodeling.

The CFCs used in mechanically producing such foams are entrained within the insulation and contribute to its desirable properties as barriers against thermal loss. In the long run, foam insulation manufacturers are looking to alternative fluorocarbons such as 123 and 141b to replace CFC-11. Until those materials are on the market, however, the industry is very vulnerable to competition from other types of insulation such as glass fiber.

"The hard facts are that a production freeze at 1986 levels is actually a reduction from the levels we are using today because we've been growing at 20% a year," says Lorraine M. Aulisio, vice president for technical services and regulatory affairs for Celotex Corp. That firm is the largest producer of rigid insulating polyisocyanurate.

The industry already has reduced its emissions from manufacturing from 10% to 5% of the CFCs used, Aulisio says, and can't expect to conserve much more in that area. She says the industry is looking at the use of extenders or blends in foamblowing.

"We must face the reality of change," Aulisio says. "We're working hard to ensure our short-term survival."

Other industries that use CFCs—such as manufacturers of other types of foams, refrigeration, and air-conditioning equipment—although facing major adjustments, are not in such desperate straits. Home air-conditioning, for example, has already switched almost entirely to CFC-22 ($CHClF_2$) from CFC-12. In refrigeration and automobile and commercial air-conditioning, large reductions in emissions could be made simply by recovering and recycling during servicing. Over the longer term, new equipment can be designed to use the expected substitutes such as 134a.

Because halons contain bromine, which reacts faster with ozone than chlorine, atmospheric chemists think those compounds are a bigger threat to stratospheric ozone than CFCs on a molecule-per-molecule basis. However, halons are subject only to a freeze, not a production cut, under the Montreal protocol. But their use has been growing so fast a freeze alone will have a major impact on producers and users.

The low toxicity and noncorrosivity of the halons have made them the agents of choice for protecting expensive or highly sensitive equipment from fires. Halon 1301 ($CBrF_3$) is used in systems that flood entire rooms containing computer installations with the chemical when a smoke detector is triggered. Personnel need not be evacuated and the halocarbon extinguishes the fire without damaging sensitive electron-

Views differ on adequacy of Montreal protocol, proposed EPA rules

The Montreal protocol—the international agreement to curtail production of fully halogenated halocarbons—is considered in many quarters to be an unprecedented achievement. "The Montreal Protocol on Substances That Deplete the Ozone Layer will become a global turning point, a model for continued worldwide cooperation between government, industry, and public interest groups to safeguard our planet," G. Victor Buxton, chief of Environment Canada's chemical control division, told last month's conference on substitutes and alternatives.

Yet like the outcome of any negotiation, the protocol is a compromise among competing interests. U.S. industry, for example, while granting the need to halt the growth in output of fully halogenated materials, thinks cuts in chlorofluorocarbon (CFC) production are unnecessary. Nevertheless, industry representatives are urging the agreement be ratified.

"A freeze is sufficient to protect the environment and provide incentives to look for alternatives," says Richard Barnett, chairman of the Alliance for Responsible CFC Policy, an association of CFC producers and users. "But since the international agreement calls for reduction we will capitulate, because the agreement is so important. Without it, our government is highly likely to do something more restrictive under pressure from environmentalists."

Indeed, Sen. Max S. Baucus (D.-Mont.) has already asked that the first of the periodic scientific reassessments built into the agreement be held ahead of schedule. "The protocol is a significant step but doesn't go far enough," he says. "Recent evidence suggests that the problem is much more serious than we thought. When the protocol was drafted we didn't know the Antarctic ozone hole was caused by chlorine."

Baucus' views are echoed by David D. Doniger, senior attorney for the Natural Resources Defense Council. He points out that even with the 50% cut in CFC production called for in the protocol, the atmospheric concentrations of halocarbons will continue to grow because of their long lifetimes. Consequently, he argues, the seasonal destruction of large amounts of ozone over Antarctica will continue to recur—and the phenomenon may spread elsewhere.

NRDC thinks the Environmental Protection Agency's proposals to enforce the Montreal protocol within the U.S. are inadequate. "The ozone layer will not be protected until the atmospheric stockpile of CFCs and halons is reduced and ultimately removed," Doniger says. "This requires a rapid, near-total phaseout of these chemicals, not merely a 10-year halfway measure."

Industry representatives, however, assert that the Montreal protocol and the proposed EPA rules are more than sufficient to protect the ozone layer. "Environmentalists argue that EPA hasn't used data from Antarctica and so should go further," says Joseph M. Steed, environmental manager for Du Pont's Freon products division. "We disagree. We think that EPA has been considering those data implicitly and that the regulations are adequate. Du Pont supports the ratification of the Montreal protocol."

---

ics. Similarly, halon 1211 (CF_2BrCl) is used in portable fire extinguishers where valuable equipment must be protected from damage by both fire and the extinguishing agents—airplane cockpits, for example.

Unlike CFCs, however, there are no known alternatives for the fire-fighting uses of halons, even in preliminary development. "There are no known substitutes and I'm not confident such substitutes will become available," says Billy Tullos, business manager for fluorocarbons for Great Lakes Chemical Corp. "The industry must respond by reducing unnecessary emissions."

Fortunately, reducing emissions may not prove too difficult. "Most halons are banked in tanks, awaiting future use," says Stephen Waters, president of Fireline Corp. "But what is emitted is for frivolous uses." For example, most emissions of halon 1301 are for discharge testing of total flooding systems.

The National Fire Protection Association (NFPA) has already backed away from a standard it had proposed that would have mandated such discharge testing. Waters points out, however, that in reality many insurance companies and fire departments require full discharge testing even though NFPA doesn't. An alternative agent that could be used in discharge tests in place of halon 1301 is needed, he says.

The military, the major user of halon 1211 for fire-fighting training, is already taking steps to curb its uses of both halons. E. Thomas Morehouse of the Air Force engineering and services fire research laboratory describes several alternatives to actual fires that are being developed for training exercises. An interactive video like a computer game that simulates an actual fire has proved so popular that it is in use 24 hours a day, he says.

EPA has announced funding for outside researchers in response to the lack of viable alternatives for halons, says N. Dean Smith, a chemist with the agency's air and energy engineering research laboratory in Research Triangle Park, N.C. The project is designed to look at completely novel compounds that have not been considered as alternatives to CFCs and halons, he says.

"The initial proposals will include synthesis of new compounds and determination of the relevant chemical properties," Smith says. "If any look favorable then we would probably follow up with atmospheric fate testing and preliminary acute toxicity tests. We'll keep industry informed and let them carry forward any promising candidates."

Industry already has an immense amount of work to do in the next decade on substitutes and alternatives for CFCs and halons. But now that restrictions on the output of those chemicals are inevitable, the race is under way. "Industry is running flat out to be the first with new compounds," says ICI's Harris. "In my 17 years with my company, I have never seen a project that received priority like this." □

The Great Lakes Cleanup Effort

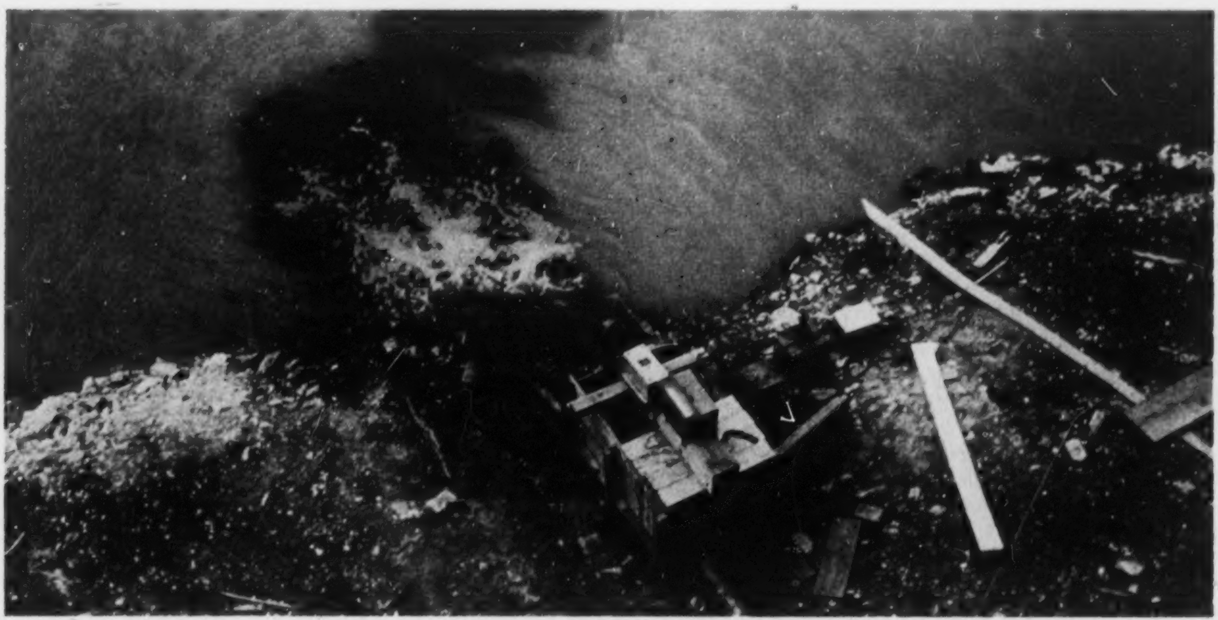
Much progress, but persistent contaminants remain a problem

Bette Hileman, C&EN Washington

The Great Lakes Basin is a complicated ecosystem without parallel anywhere in the world. Some have suggested that the ecosystem is in severe environmental difficulty, like a hospital patient staying alive only with a life support unit. A more accurate description might be that it is like a victim that was once about to lose one of its limbs, but now the limb has recovered to a large degree, although the whole body still suffers from a pervasive sickness.

The effort to clean up the Great Lakes began in 1972. In some ways, it has been successful. Other regions that intend to clean up large bodies of water, such as the Chesapeake Bay, are using the Great Lakes agreements as models of cooperation between different jurisdictions.

However, efforts to address the problem of persistent toxic substances in the Great Lakes are just beginning. During the past few years, scientists have learned that more than half the toxic substances deposited in some of the lakes are airborne. These are particularly



Michigan Department of Natural Resources photo

Outflows such as this into one of the Great Lakes are a major contributor to high pollution levels hard to deal with. Also, more and more evidence has accumulated that toxic substances are causing fish tumors, birth defects in birds, and possible reductions in otter and mink populations. Their effects on human health are still uncertain and controversial.

One very positive recent step, meanwhile, is a new process created for developing remedial action plans for cleaning up so-called areas of concern—heavily polluted harbors, connecting channels, or river mouths near major municipal or industrial centers.

For nearly two centuries, the Great Lakes were thought to be almost immune from pollution because they are so large. They contain at least 95% of the surface fresh water in the U.S. and 20% of the world's fresh water. About two fifths of U.S. industry and about half of Canada's industry are located in the basin. Nearly 37 million people make their home there.

Owing to the lakes' immensity, it was believed for many years that almost any amount of waste could be dumped into them without affecting their integrity. And indeed, almost anything was put into them for nearly two centuries. They and the rivers leading into them served as large lagoons for sewer outfalls, depositories for industrial wastes, dumpsites for dredged polluted sediments, sinks for farmland and urban runoff.

But even the lakes have a dumping capacity that can be exceeded. The system is relatively closed. Less than 1% of the total volume of water in the system flows out the St. Lawrence River each year. Lakes Superior, Michigan, and Huron have especially long water retention times, which makes them particularly susceptible to pollutant buildup. On the average, water that enters Lake Superior takes 182 years to be flushed out again, for Lake Michigan it takes 106 years, and for Lake Huron 21 years. On the other hand, Lake Erie is flushed once every 2.7 years.

During the 1960s, observable pollution reached an extreme in the southerly third of the Great Lakes Basin. Henry A. Regier, zoology professor at the University of Toronto, called it "a vast ecological slum." With little government interference, industries were putting increasing amounts of wastes into the air, water, and land. Farmers were using large quantities of DDT and other persistent pesticides, and these were reaching the lakes through farmland runoff and atmospheric deposition. Sewers and sewage treatment plants were dumping rich loads of nutrients into the lakes and rivers leading into them. Wetlands near the lakes were being filled with waste soil and rubble.

In contrast, the middle third of the basin had been less damaged. Problems were apparent only in certain locales. In the northern third of the basin, the damage was even less obvious, except near mines and pulp mills.

By 1970, Lake Erie had lost nearly all its native fish. Algal mats covered the nearshore areas and the water had a noticeable odor. A *Life* magazine cover story in 1970 declared Lake Erie dead, and many believed that cleaning up the lake would be nearly impossible. Sport and commercial fishing for native fish had come to a virtual halt in both Lakes Erie and Ontario.

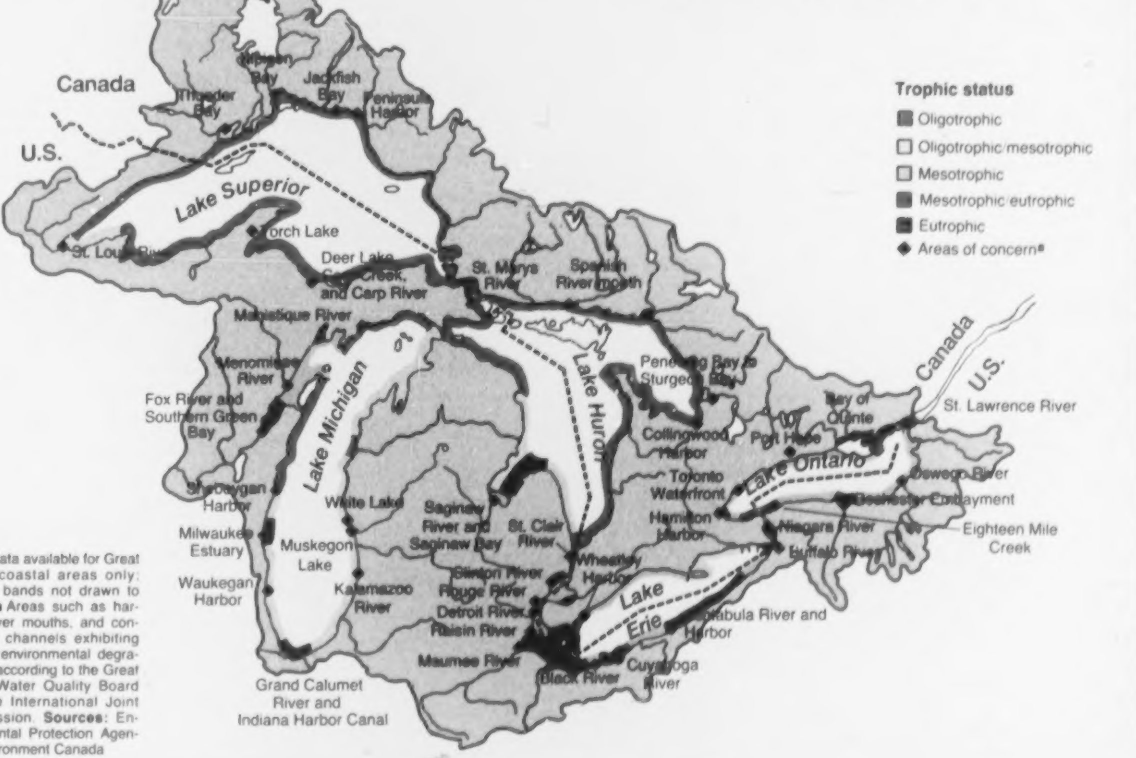
In 1972, the U.S. and Canadian governments responded to growing concern about deteriorating water quality in the Great Lakes by signing the first Great Lakes Water Quality Agreement. The agreement addressed primarily conventional pollutants—phosphorus, oil, and visible solid wastes. One of its goals was to reduce phosphorus to no more than 1 ppm in discharges from large municipal sewage treatment plants into Lakes Erie and Ontario, together with new limits on phosphorus from industrial plants. Implementation of the agreement was monitored by the International Joint Commission (IJC), an independent U.S.-Canadian agency created by the Boundary Waters Treaty of 1909 to advise and otherwise assist the governments under the treaty. Two bilateral groups were established to advise members of the IJC—the Water Quality Board and the Science Advisory Board.

Visible evidence of progress was apparent during the first five years after the agreement was signed. By spending more than $10 billion, governments reduced the total discharge of phosphates into Lake Erie and Lake Ontario drastically. Algal mats largely disappeared from Lake Erie, and the waters of Lake Erie and Lake Ontario looked and smelled better. Foul and unpleasant waterfronts that had been abandoned for all purposes except heavy industrial use were devel-

North shore of Lake Superior is still largely wild and uninhabited

Leanne Klyza Linck photo

Great Lakes Basin still has many areas with pollution problems


Canada
U.S.
Nipigon Bay
Jackfish Bay
Thunder Bay
Peninsula Harbor
Lake Superior
Torch Lake
St. Louis River
Deer Lake, Carp Creek, and Carp River
St. Marys River
Spanish River mouth
Manistique River
Menominee River
Fox River and Southern Green Bay
Lake Michigan
Lake Huron
Penetang Bay to Sturgeon Bay
Bay of Quinte
Canada
U.S.
St. Lawrence River
Collingwood Harbor
Port Hope
Lake Ontario
Toronto Waterfront
Oswego River
Rochester Embayment
Hamilton Harbor
Niagara River
Eighteen Mile Creek
Buffalo River
Sheboygan Harbor
White Lake
Saginaw River and Saginaw Bay
St. Clair River
Milwaukee Estuary
Muskegon Lake
Wheatley Harbor
Waukegan Harbor
Kalamazoo River
Clinton River
Rouge River
Detroit River
Raisin River
Lake Erie
Ashtabula River and Harbor
Maumee River
Black River
Cuyahoga River
Grand Calumet River and Indiana Harbor Canal
Trophic status
▨ Oligotrophic
☐ Oligotrophic/mesotrophic
☐ Mesotrophic
▨ Mesotrophic/eutrophic
■ Eutrophic
◆ Areas of concern[a]

Note: Data available for Great Lakes coastal areas only; coastal bands not drawn to scale. [a] Areas such as harbors, river mouths, and connecting channels exhibiting serious environmental degradation, according to the Great Lakes Water Quality Board and the International Joint Commission. **Sources:** Environmental Protection Agency, Environment Canada

oped as tourist areas. Sportfish began to return to Lake Erie, and the Cuyahoga River in Cleveland no longer caught fire occasionally as it had in the sixties.

However, during those five years it also became obvious that a number of problems had not been addressed by the original agreement. Fish in many areas of the lakes were heavily contaminated with polychlorinated biphenyls (PCBs), mirex (an insecticide and fire retardant), heavy metals, and other chemicals. Scientists gradually discovered that important sources of pollutants to the lakes had been overlooked the first time around. These included runoff from farmland and city streets; industrial discharges of pollutants other than the conventional waterborne pollutants (biochemical oxygen demand, suspended solids, and toxic metals); airborne toxic substances; contaminated groundwater; and polluted sediments. Researchers also concluded that phosphorus limits should be imposed for the upper lakes—Huron, Michigan, and Superior.

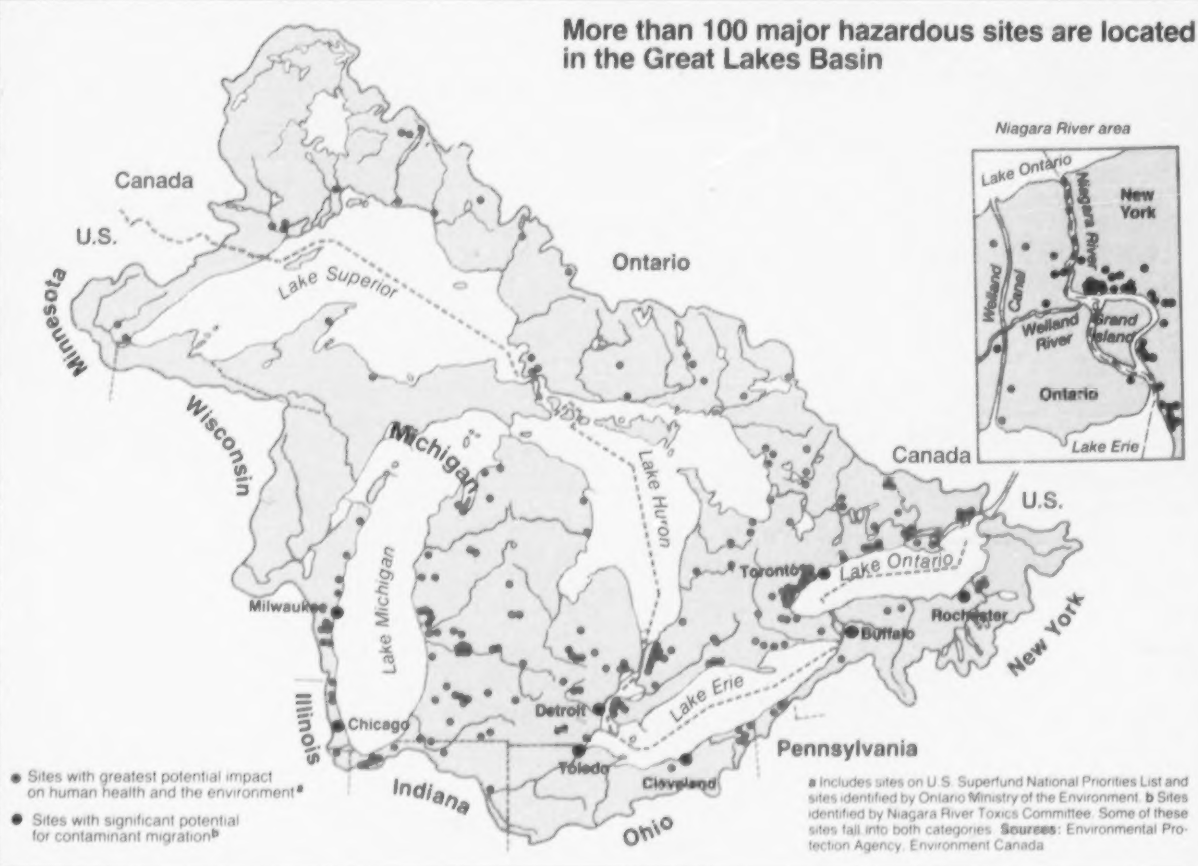
As a result, the U.S. and Canada signed a new water quality agreement in 1978. It established as a goal the virtual elimination of discharges of toxic chemicals. It also set more stringent overall reductions in phosphorus loadings for Lakes Erie and Ontario and for the first time set limits for the upper lakes. For the first time, the agreement also adopted an ecosystem approach to cleaning up the basin "to restore and maintain the integrity of the waters of the Great Lakes basin ecosystem."

The 1978 agreement states that about 350 "hazardous polluting substances" should be banned from the lakes. Of these, the Water Quality Board of the IJC later identified 11 substances as critical pollutants. These are lead, mercury, hexachlorobenzene, PCBs, polynuclear aromatic hydrocarbons such as benzo[a]pyrene (BaP), 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (2,3,7,8-TCDD), 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-TCDF), and four organochlorine pesticides: mirex, DDT, dieldrin, and toxaphene.

Because progress in reducing the levels of several of these compounds in water and biota seemed to have come to a virtual standstill and because a joint National Research Council-Royal Society of Canada report pointed out many areas in which the 1978 agreement needed strengthening, both governments reviewed it in 1987. On Nov. 18, 1987, amendments to the agreement were signed by Environmental Protection Agency Administrator Lee Thomas and Canada's Environment Minister Thomas McMillan.

The new amendments reflect technical knowledge gained since 1978 and tighten up accountability and management. They set responsibilities and dates for completion of various milestones and reports, and

More than 100 major hazardous sites are located in the Great Lakes Basin


Canada
U.S.
Minnesota
Lake Superior
Ontario
Wisconsin
Michigan
Lake Michigan
Lake Huron
Canada
U.S.
Milwaukee
Toronto
Lake Ontario
Rochester
Buffalo
New York
Lake Erie
Illinois
Chicago
Detroit
Pennsylvania
Toledo
Cleveland
Indiana
Ohio
Niagara River area
Lake Ontario
Niagara River
New York
Welland Canal
Welland River
Grand Island
Ontario
Lake Erie

● Sites with greatest potential impact on human health and the environment[a]

● Sites with significant potential for contaminant migration[b]

a Includes sites on U.S. Superfund National Priorities List and sites identified by Ontario Ministry of the Environment. b Sites identified by Niagara River Toxics Committee. Some of these sites fall into both categories. **Sources:** Environmental Protection Agency, Environment Canada

they stipulate a process for reviewing water quality goals and for preparing remedial action plans for the areas of concern. "As important as anything else, the amendments set new deadlines for reducing pollution," McMillan said during the signing ceremony.

In general, early progress in cleaning up the Great Lakes was relatively straightforward and simple, though expensive, and the results were obvious. Except for the heavily polluted areas of concern, future progress in cleaning up the lakes will be far more difficult to observe and probably also far more expensive. It will be seen in future fish advisories, as fish that are now considered too polluted to eat are given a clean bill of health, and in the receipts of commercial fishermen, as they are allowed to sell fish from more areas of the lakes.

As Thomas Brydges, scientist at Environment Canada (the Canadian equivalent of the U.S. EPA), explains, "Most of the problems that remain are subtle and in some areas it is hard to tell whether toxics really are causing damage. The problem of persistent toxic substances is the foremost problem confronting the Great Lakes. It will take more money and effort to control this problem than it has in the past."

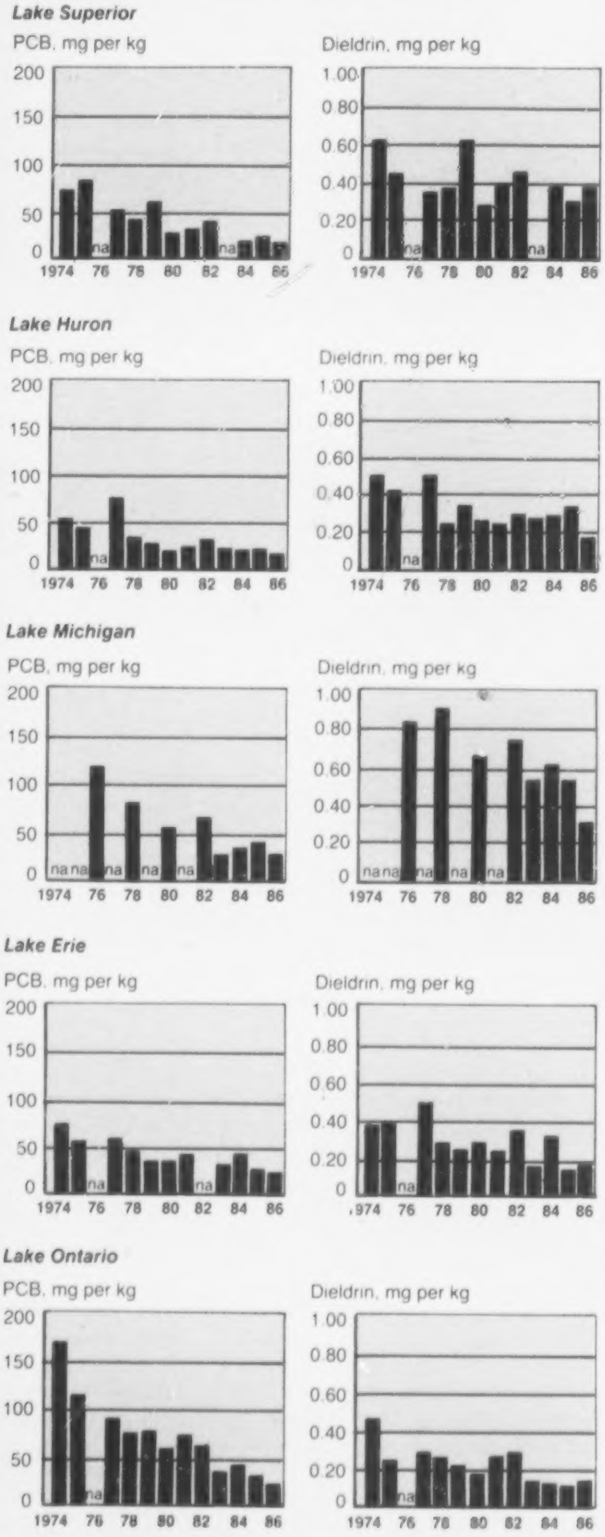
The current overall condition of the lakes is fair to excellent in regard to phosphorus, deteriorating in regard to nitrogen, and mixed in regard to toxics. The levels in water and biota of some toxics that have been restricted or banned, such as lead and DDT, have declined dramatically. Other persistent toxics have decreased only to a still unsatisfactory level. And some actually have increased.

Biological productivity is one way to measure the health of the lakes. This is the amount of living material supported within them, mostly in the form of algae. The least productive lakes are called oligotrophic, those with medium productivity mesotrophic, and those with the greatest productivity eutrophic. Several factors influence productivity—nutrients (nitrogen and phosphorus) received from the environment, temperature, light, and depth and volume of water.

Though high productivity might sound like a positive attribute, it is unnatural for a large lake to be eutrophic or even mesotrophic. Before European settlement and industrialization, all the Great Lakes were oligotrophic except in marshes and shallow bays. Algal growth was low and the waters were clear.

The use of synthetic fertilizers and phosphate detergents adds enormously to the amounts of phosphorus and nitrogen available to the lakes. It stimulates the growth of green plants, including algae, just as adding fertilizer to a lawn stimulates its growth. When algae increase, bacteria that decompose the algae also

PCB, dieldrin levels in herring gull eggs from Great Lakes colonies are declining



na = not available **Source:** Great Lakes Water Quality Board

increase. The bacterial degradation of algae requires oxygen, and therefore depletes the water column of oxygen that otherwise would be available to fish. Marine animals that require little oxygen, such as sludge worms and carp, then proliferate. Demand for oxygen through decay of organic matter is called biochemical oxygen demand (BOD).

Today, the nearshore areas of all the Great Lakes except for Lake Superior suffer eutrophication problems. Because Erie is the shallowest and warmest of the lakes and has a large concentration of agriculture in its drainage basin and a highly urbanized shoreline, it suffered the greatest eutrophication in the sixties, before phosphate control began. Even now, "There is still high oxygen depletion in the bottom waters in the central basin of Lake Erie," says Valdus V. Adamkus, administrator of EPA Region V and U.S. cochairman of the Great Lakes Water Quality Board.

When the water quality agreement was signed in 1972, it was determined that reducing phosphorus inputs was the most direct way to solve the eutrophication problem. This is the success story of the Great Lakes cleanup. Phosphorus loadings to Lake Erie and Lake Ontario were cut about 80% by upgrading sewage treatment plants and decreasing the amount of phosphate allowed in detergents in the basin. However, Ohio and Pennsylvania still have not passed laws limiting the amount of phosphates used in detergents. At press time, the Ohio House had passed such a bill, but the Ohio Senate had not acted on it. "Ohio has not been very successful in many Great Lakes programs until just recently," says Robert Boggs, state senator from Ohio.

Efforts today to further reduce phosphorus loadings are focused on three areas: bringing more municipal wastewater treatment plants into compliance with the phosphorus limit of 1 mg per L of output; control of agricultural runoff through conservation tillage, fertilizer management, and animal waste management; and better monitoring of industrial point sources capable of releasing more than 1 metric ton of phosphorus per year.

Adamkus says EPA is generally "quite happy with compliance of U.S. municipal sewage treatment plants, but that financially strapped plants still do not comply." He adds that through very aggressive enforcement the U.S. "will try and meet the goal by July 1988."

Canada likewise reports progress. James N. Bishop, director of the water resources branch of the Ontario Ministry of the Environment, says that during the past two years there has been improvement in terms of overall loading, but that "the number of plants out of compliance is still high." These facilities, however, are either small or are only a little over the target. Ontario will begin to impose fines during the next two years on municipal and industrial plants that do not comply with emission goals, he says.

Agricultural initiatives in both countries are also being used to control phosphorus inputs. In the U.S., the adoption of conservation tillage (a method of planting crops without plowing the land) already has substantially reduced phosphorus runoff. In the fu-

C&EN staff photo

EPA Administrator Lee Thomas, Canada's Environment Minister Thomas McMillan sign amendments to the 1978 Great Lakes Water Quality Agreement

ture, the U.S. plans to use existing programs to continue to encourage the adoption of conservation tillage. The Water Quality Board reports, however, that "the acceleration of U.S. phosphorus reduction programs called for in the [target load] plan is not taking place, particularly for programs supporting changes in tillage practices."

In contrast, the Canadian effort to reduce phosphorus inputs from agriculture will be carried out with a new program, called Soil & Water Environmental Enhancement Program (SWEEP), to improve soil management and conservation practices on farms in the Lake Erie basin. Phosphorus from cropland sources will be reduced 200 metric tons (10%).

Fish manipulation strategies also can affect phosphorus levels in the lakes. When the population of large fish increases, more small forage fish are consumed. Because these forage fish eat zooplankton, the number of zooplankton that eat algae rises, so that more algae are consumed, clarifying the water. "It's not a simple situation," Regier explains. "There is a synergism in the recovery process, but it is not clear how these things interact. Bringing in big fish does help clarify the water, and keeping phosphate out also helps."

Nitrogen (measured as nitrate and nitrite) enrichment of the lakes is an issue that is not discussed very much, nor do its consequences seem to be very well understood. However, nitrogen levels have been rising in all five lakes. The annual rates of increase in open water range from 4.96 μg per L for Lake Superior to 10.03 μg per L for Lake Ontario. These increases appear to be largely caused by man.

Actions taken to reduce agricultural runoff of phosphorus will, of course, also decrease nitrogen inputs, as will efforts to cut back automobile emissions of nitrogen oxides. No focused program to reduce nitrogen inputs to the Great Lakes has been undertaken, however, and little research has been done on the effects of nitrogen on aquatic life. According to EPA, only 8% of publicly owned treatment works in the basin provide high-level nitrogen control.

Timothy J. Kubiak, environmental contaminants specialist with the U.S. Fish and Wildlife Service, says nutrients in a lake interact with the toxic contaminants. For example, if the total amount of organic material, whether algae or particulate matter, is reduced, there is less of it to scavenge or adsorb toxic chemicals. Therefore more of the toxic chemicals may remain dissolved and the water quality may appear worse than otherwise.

Toxic contaminants a major issue

The issue of toxic contaminants in the Great Lakes in some ways seems hidden and subtle because generally the effects cannot be seen directly. Toxics do not cause obvious observable effects, such as algal mats and foul smelling turbid water. The levels of many of the contaminants in water are nondetectable, even with the best scientific instruments. Also, "At present, no concentrations of chemicals or heavy metals are found in the lakes at levels that are known to be acutely toxic to organisms during brief exposure," the EPA Great Lakes Office reports.

Between 1969 and 1972, legislation restricted or banned the use of dieldrin, heptachlor, DDT, PCBs, mercury, and mirex within the Great Lakes Basin. In general, concentrations of many of these contaminants declined significantly. The greatest decrease occurred between the mid-1970s and the early 1980s, with subsequent levels remaining fairly stable.

For the majority of organic chemicals among the critical pollutants, concentrations in most parts of the lakes are now so low that they meet the agreement standards. But in the areas of concern and in other nearshore areas at the mouths of tributaries, the levels of some of these organics are high.

PCB levels are an exception. They are higher than agreement levels of 1 ng per L in the western regions of Lakes Erie and Ontario as well as in Lake Michigan.

For metals on the list of critical pollutants, the situation is similar. In open lake waters, the levels are generally fairly low. But in many nearshore areas and in areas of concern, concentrations exceed the 1978 agreement objectives.

Though the water levels of some critical pollutants are high in some areas, the major concern about these pollutants is the effects they have on aquatic life and fish-eating birds as they bioaccumulate up the food chain. There is also concern about possible additive and synergistic actions of toxics on aquatic life, birds, and humans. The concentrations of some chemicals in the fat tissue of top predators, such as lake trout and salmon, can be a million times higher than the levels in the water.

Phytoplankton filter the water for nutrients and in the process scavange persistent chemicals such as PCBs. Phytoplankton, in turn, are eaten by zooplankton and these by bottom-dwelling fish such as rainbow smelt. Predators such as lake trout and salmon at the top of the food chain then consume the bottom-dwelling fish. John J. Black, cancer research scientist at Roswell Park Memorial Institute, Buffalo, N.Y., calculates that to get as large a dose of PCBs as in 2 lb of lake trout contaminated with 2.5 ppm of PCBs (as many unrestricted sportsfish are), one would have to drink the Great Lakes water it lives in for 1000 years. Persistent toxics are biomagnified in fish-eating herring gulls and their eggs to an even greater degree than they are in fish.

High levels of contaminants in some species of fish have led to the issuance of fish consumption advisories. The larger, older fish in a species are most likely to be restricted. Nursing mothers, pregnant women, women who anticipate bearing children, and children under 15 are advised not to eat lake trout over a certain size from Lakes Michigan, Superior, Huron, and Ontario. In addition, men and women of all ages are advised against eating very large lake trout in all five lakes.

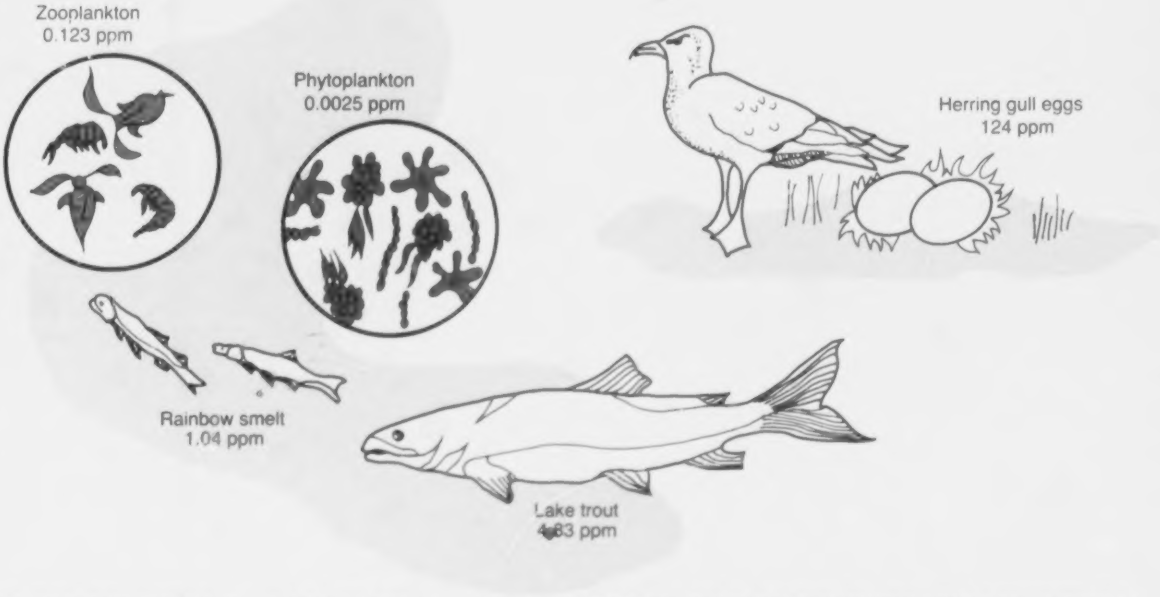
Contamination also has led to waterfowl advisories. The New York Department of Environmental Conservation has tested seven species of waterfowl for PCBs and organochlorine pesticides. Birds originating near Lake Ontario were found to have significantly higher concentrations of PCBs than birds in other flyways, except for the Hudson River, and were the only birds containing mirex. High levels of PCBs have caused waterfowl advisories to be issued for certain species of waterfowl in New York and Wisconsin.

Fish tumor outbreaks

Outbreaks of certain types of fish tumors, especially in heavily polluted areas such as harbors and the mouths of rivers, are believed to result from contaminants in the Great Lakes Basin. Fish tumors have been identified in 14 of the 42 areas of concern; for 24 of them no data exist on fish tumor incidences.

Even though the relationship between fish cancers and contaminants is not understood completely, recent research points more and more to pollutants as the only plausible cause of certain types, particularly those of the liver. John Harshbarger, director of the registry of tumors in lower animals at the National Museum of Natural History, says that all but one of

Toxic chemicals such as PCBs are biomagnified in the aquatic food chain



Phytoplankton collect the nutrients necessary for plant growth from a relatively large volume of water. In the process, they also collect persistent contaminants that may be in the water at concentrations so low they are undetectable even with very sensitive instruments. Small fish and zooplankton eat vast quantities of phytoplankton and further concentrate any chemicals accumulated by the phytoplankton. This biomagnification is repeated at every step of the food chain. Thus, as the diagram indicates, the concentration of polychlorinated biphenyls in rainbow smelt can approach 500 times that in the phytoplankton and the concentration in gull eggs can be 50,000 times higher.

Predators at the end of the food chain, such as lake trout, large salmon, and herring gulls, may accumulate levels of a toxic chemical high enough to cause serious deformities or death. Because they are at the end of the aquatic food chain, the eggs of fish-eating birds often have the highest levels of toxic chemicals. Consequently, dead or defective chicks are sometimes the first visible sign of contamination in the Great Lakes the outbreaks of fish liver tumors he is aware of have occurred in areas with obvious sources of pollution.

"There are lots of other sites that are unpolluted where fish have cancer, but they are other types of cancer," he explains. He gives several examples of sites in the Great Lakes Basin where outbreaks of liver cancer have been found: the Niagara River, the mouth of the Cuyahoga River, the Buffalo River, and the Black River that empties into Lake Erie.

Because of the complexity of the natural environment, it may never be possible to prove absolutely a causal relationship between chemical contaminants in a waterway and liver cancer in fish. However, the "circumstantial evidence is so strong, it is almost impossible to deny," Harshbarger notes. He offers several reasons why liver tumors are associated with pollution:

- People had been looking for liver tumors in wild fish since the 19th century, but the first case was not found until 1964.
- In the lab, more than two dozen species of fish have been exposed to more than three dozen known mammalian chemical carcinogens and virtually every species developed liver tumors. Various other types of cancer also occurred fairly often, but not with the consistency of liver cancer.
- Roswell's Black applied extracts of sediments from two of the polluted areas where wild brown bullheads and catfish have cancer to the skin of healthy brown bullheads. He produced skin and liver tumors resembling those of the wild fish.
- Wild fish with liver cancer tend to be clustered where synthetic organic pollutants are concentrated.
- Scientists have failed to find any other cause, such as viruses or a genetic factor, for the liver cancers of fish in polluted areas.

Contaminants may be responsible for a number of other fish problems. Nearly 100% of coho salmon in Lake Erie have goiters. "They also lack secondary sex characteristics, have impaired lipid metabolism, are unusually small, and 75% of the embryos die," Harshbarger explains.

Birds and mammals

Toxic pollution also seems to be related to reproductive failure and birth defects among certain types of birds that feed on Great Lakes fish. Some of the affected species are herring gulls, double-crested cormorants, caspian terns, and Forster's terns.

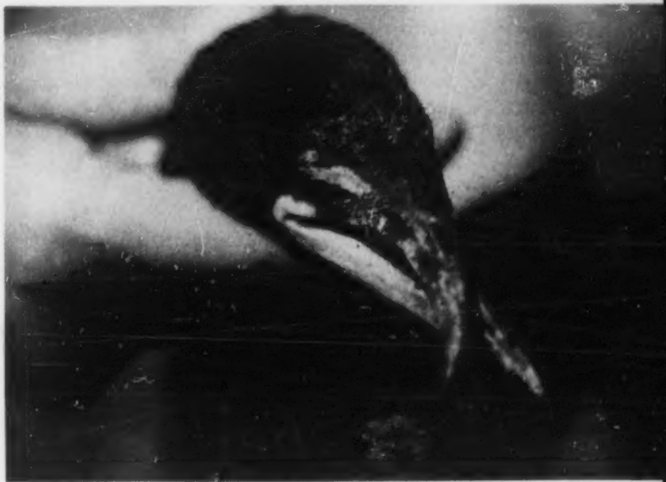
By the late 1960s, cormorants on the lakes had been almost extinguished by a combination of human intervention and DDT contamination, which caused the eggs to fail because of thin shells. In an effort to save fish from cormorant predation, commercial fishermen often destroyed cormorant eggs and the Ministry of Natural Resources in Ontario used to spray a mixture of formaldehyde and soap on the eggs to kill the embryos while leaving the eggs intact. James P. Ludwig of Ecological Research Services in Bay City, Mich., estimates that the total Great Lakes cormorant population probably reached a low of 200 nesting pairs sometime between 1968 and 1973. By 1981, after DDT was banned and the deliberate destruction of eggs stopped, the population had grown to about 3000 nesting pairs. Now it is estimated to be 10,000 pairs.

Unfortunately, at the same time the cormorant population increased, the percentage of cormorant chicks with a crossed-bill defect also may have risen. The first cormorants with crossed bills were seen in 1979, reports Kubiak of the U.S. Fish & Wildlife Service. Since then, he and other investigators found more than 60 birds with crossed bills mostly where Green Bay and Lake Michigan meet; none have been found in sites on Lake Superior, where the water quality is much better. Chicks with crossed bills generally live no more than a few weeks because their bills are useless for catching fish.

Ludwig and his coworkers have studied cormorant and caspian tern eggs from 12 colonies on the shores of Michigan. The percentages of defective embryos correlate well with the degree of contamination of the nesting sites. For example, cormorant and tern eggs from nests at a Saginaw Bay facility containing contaminated sediments had very high rates of defective embryos. None of the birds from these eggs fledged. "The wide distribution of defective tern and cormorant embryos suggests that all Michigan waters of Lake Huron and Lake Michigan are still significantly contaminated," Ludwig reports.

David J. Hoffman of the U.S. Fish & Wildlife Service and his coworkers, including Kubiak, also have studied reproductive success in Forster's terns at a colony on Green Bay. The hatching success of the Green Bay eggs was 52% of that at a control lake where the water quality is considerably higher. A new paper on this research proposes that certain dioxinlike PCB cogeners may be causing the reproductive problem.

There is evidence, too, that contaminants in Great Lakes fish also may be affecting mink and river otters, both of which eat fish. The state departments of natural resources in Wisconsin and Michigan have found


Timothy J. Kubiak photo

Number of cormorant hatchlings with crossed bill defect seems to have increased in the past few years that fewer otters are trapped near Lake Michigan than near Lake Huron.

Robert Foley, a biologist with the New York Department of Environmental Conservation, has found that the levels of organochlorine compounds in the organs of mink and river otter are highest in animals that live in areas close to Lake Ontario and in the Hudson River valley. The levels of PCBs he measured in some wild mink are as high or higher than levels that cause reproductive problems in controlled studies conducted on mink farms.

Clearly, more studies of birds and mammals in the Great Lakes Basin need to be done to better understand the causes of defective embryos and reproductive failures and to learn more about the extent of contamination problems.

Human health effects

Like everyone who lives in an industrial nation, people who inhabit the Great Lakes Basin are exposed to a large number of chemicals through a variety of pathways. Some observers believe, however, that exposure is higher than average for inhabitants of the basin. The joint NRC-Royal Society of Canada review of the Great Lakes agreement states: "The committee finds substantial evidence from the results of studies done by both the U.S. and Canada that the human population living in the Great Lakes Basin is exposed to, and accumulates, appreciably more toxic chemical burden than other human populations in similarly large regions of North America for which data are available."

Many scientists believe that the greatest exposure to toxics in the Great Lakes Basin probably comes from fish. Commercial fishermen and their families, sportfishermen and their families, and native North Americans who traditionally use fish as a large part of their diet continue to eat quantities of fish that far exceed the guidelines established by the U.S. and Canada. Even people who strictly adhere to the guidelines may be subject to a greater risk from fish than from other risky foods or other environmental exposures. For example, EPA estimates that the lifetime risk from eating one-fourth pound of mixed Lake Michigan fish per week is more than two orders of magnitude higher than that from eating 2 oz of peanut butter per week (usually contaminated with the natural mold aflatoxin) or of eating one-fourth pound of charcoal-broiled steak. Yet, a person who consumes that much fish is not exceeding the guidelines.

Harold E. B. Humphrey, an environmental epidemiologist with the Michigan Department of Public Health, has found that blood serum levels of PCBs and DDT are significantly higher in people who eat Great Lakes fish compared with those who do not. He also found a positive correlation between the length of time fish were eaten and blood levels of PCBs and DDT.

In addition, there is some evidence that other foods produced in the basin are more heavily contaminated with PCBs than those produced outside it. In 1976, Peter W. Saschenbrecker, analytical chemist at Agriculture Canada, found that PCB levels in Canadian beef are much higher in Ontario and Quebec (that is, the Great Lakes Basin and its outlet the St. Lawrence) than in the Atlantic or western provinces.

Breast milk, too, has a higher PCB level in Ontario (21 ppb) than elsewhere in Canada. In 1984, anthropologist B. Jill Smith found PCB levels of 45 ppb in breast milk of fish-eating women in Sheboygan, Wis., compared with 38.5 ppb in the milk of nonfish-eating women. An infant weighing 4 kg who drinks 600 mL a day of milk contaminated with 45 ppb of PCBs consumes 6.75 μg per kg of body weight per day of PCBs, more than six times the maximum daily PCB safe dose set by the U.S. Food & Drug Administration. Studies by Joseph L. Jacobson of Wayne State University and his coworkers and Greta G. Fein of the University of Maryland and her associates have found that smaller birth sizes, lower gestational age, and neonatal behavioral deficits correlate with the mothers' consumption of contaminated fish. Though PCBs in fish seem a likely cause, other contaminants may be involved, the authors warn.

Controversial study

A recent report "Toxic Chemicals in the Great Lakes Basin Ecosystem: Some Observations," prepared by two employees of Environment Canada, has aroused a great deal of controversy. After more than a year's delay, Environment Canada paid for printing and circulating the report but did not make it an official publication.

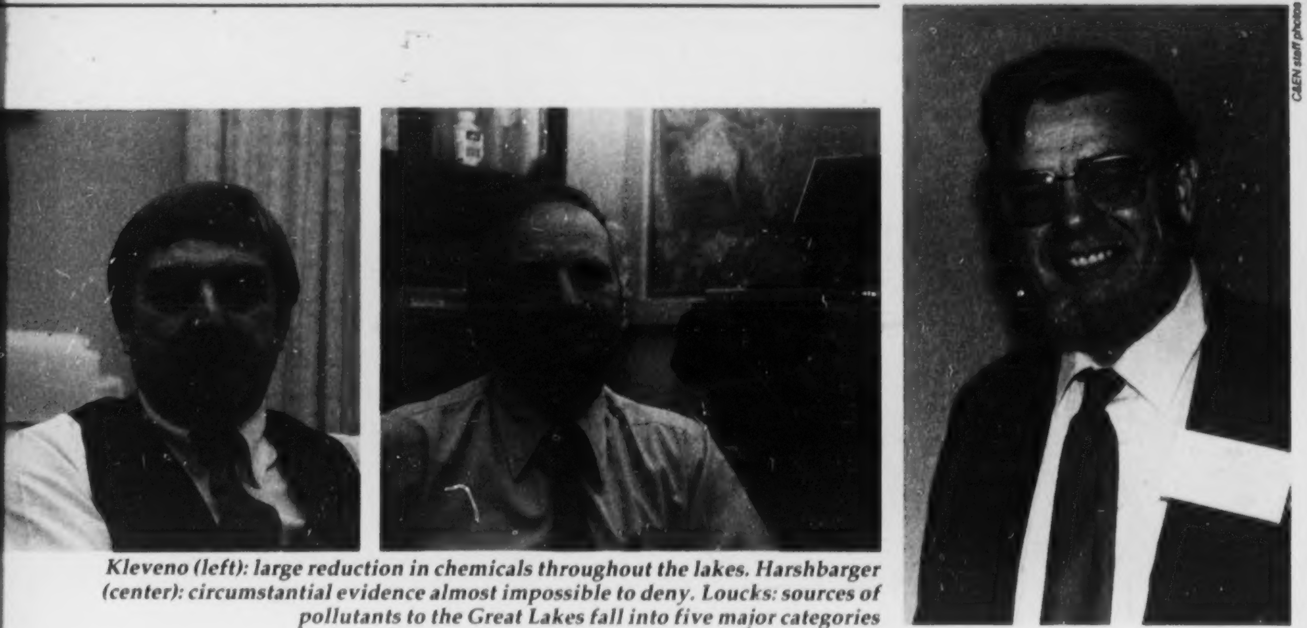
The authors, Tom Muir, an economist, and Anne Sudar, a sociologist, summarized hundreds of scientific articles to correlate levels of contaminants in Great Lakes water, sediments, and biota with health effects on fish, birds, wild mammals, and humans.

In the report, the authors say that overall cancer death rates are higher in the Great Lakes Basin and the St. Lawrence River valley than in many other parts of the U.S. and Canada. They also find higher rates of heart disease and birth defects among Canadians in the Great Lakes Basin and in the St. Lawrence River valley than in most other regions of Canada.

Even though Muir and Sudar point out repeatedly that apparently similar trends do not prove a cause and effect relationship, it is the juxtaposition between the discussions of pollution levels and of human health effects that seems to have aroused the strongest objections from reviewers. They believe such juxtaposition leads the reader to conclude there is a cause and effect relationship.

Environment Canada says it is not publishing the report as an official document because "frequently in the text, two coincident sets of data are presented, one on the environmental occurrence of some toxic chemical (or mix of chemicals), the other on some sort of biological disorder. However, the authors draw no conclusion, knowing that they have not been able to do more than point out a coincidence. Without a more systematic approach, such observations are often misleading rather than helpful."

Canadian scientists contacted by C&EN, nearly all



C&EN staff photos

Kleveno (left): large reduction in chemicals throughout the lakes. Harshbarger (center): circumstantial evidence almost impossible to deny. Loucks: sources of pollutants to the Great Lakes fall into five major categories

of whom spoke off the record, are very strongly divided over the merits of the report. Those who favor it call it "very important, a revolutionary document akin to a 'Silent Spring' for people rather than birds." Those who oppose it call it "unscientific and misleading."

Whatever the merits of the report, it has one outcome that its critics consider positive. Because of the controversy over the Muir-Sudar report and the interest it aroused, a similar study will be undertaken by two Canadian agencies—Health & Welfare and Environment Canada—that in the past have been uncooperative and have not carried out joint projects. The Conservation Foundation, Washington, D.C, and the Institute for Research on Public Policy, Ottawa, will be covering the same issues in a book to be released in 1989. It will review the problems associated with making policy decisions under conditions of scientific uncertainty.

Sources of toxics

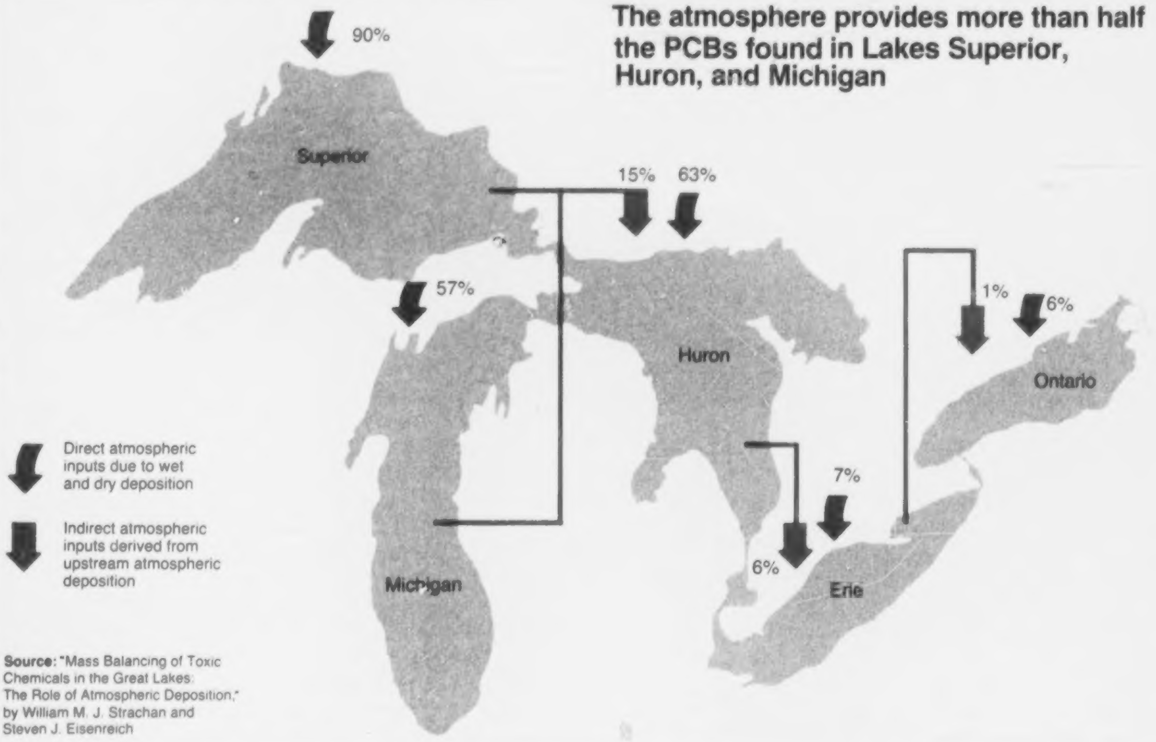
When the first water quality agreement was signed in 1972, it was generally thought that the two major sources of pollutants to the Great Lakes were municipal wastewater treatment plants and industrial discharges. If these two sources could be shut off, it was believed, most of the Great Lakes problems would be over. Gradually, however, more and more sources of pollutants came to be recognized as important. Now, the understanding is that over the whole basin, "the pollutants are divided about equally among five sources: the atmosphere, municipal and industrial point source discharges, farmland and municipal runoff, contaminated groundwater, and contaminated sediments," says Orie L. Loucks, director of the Holcomb Research Institute at Butler University in Indianapolis and coauthor of the joint academy review. Of these, the importance of airborne contaminants deposited in rain and snow, in airborne particulates, and as vapor has been recognized most recently.

Probably the most dramatic demonstration of airborne pollution came from the discovery in 1982 of toxaphene contamination of fish in a lake on Isle Royale in Lake Superior. Isle Royale is a national park with no human population and no sources of industrial contamination. The only plausible way toxaphene could have reached a lake on the island was through the atmosphere. Also, it came to be recognized that the levels of contaminants that were being measured in some of the lakes, particularly Lake Superior, could not be explained without atmospheric inputs. Lake Superior has a higher concentration of dieldrin (a banned pesticide) and only a slightly lower concentration of PCBs than three of the other lakes. Since Lake Superior is largely isolated from industrial and municipal sources, these substances must be transported by air throughout the basin.

Now it is believed that more than half the inputs of toxics to Lake Superior come from the atmosphere. For example, Steven J. Eisenreich, professor of environmental engineering sciences at the University of Minnesota, estimates that 90% of the PCBs in Lake Superior come from that source. Also, "For upper Lakes Michigan and Huron, we think the source of pollutants is primarily atmospheric," Eisenreich says. In general, the larger the surface area of the lake and the more remote it is from industrial and municipal sources, the larger is the percentage of atmospheric input.

The sources of airborne toxics to the lakes are numerous and some are believed to be very distant from the Great Lakes Basin. Also, some result from legal and generally accepted methods of waste disposal: the disposal of contaminated sewage sludge on land, the open lagoon treatment of toxic wastes (particularly by aeration), municipal waste incineration, sewage sludge incineration, and the stripping of groundwater to purify it. (Stripping is the forced removal of volatile contaminants from contaminated water to the atmosphere.)

The atmosphere provides more than half the PCBs found in Lakes Superior, Huron, and Michigan


90%
Superior
15%
63%
57%
Huron
1%
6%
Ontario
7%
6%
Erie
Michigan
Direct atmospheric inputs due to wet and dry deposition
Indirect atmospheric inputs derived from upstream atmospheric deposition

Source: "Mass Balancing of Toxic Chemicals in the Great Lakes: The Role of Atmospheric Deposition," by William M. J. Strachan and Steven J. Eisenreich

EPA and Environment Canada are jointly developing a study for the IJC of the total emissions of airborne toxics over the entire U.S. and Canada. The investigation is restricted to substances on IJC's list of critical pollutants and three additional pollutants—cadmium, arsenic, and lindane. The study makes no effort to estimate how much of these emissions actually are deposited on the Great Lakes. However, because many of the sources are located in or near the Great Lakes Basin, a significant part of the total emissions must find its way into the lakes. Pollutants whose usage is now severely restricted in the U.S. and Canada may be finding their way into the lakes from sources as far away as Latin America.

The total airborne emissions of some of the pollutants investigated are extremely large, in the range of hundreds of metric tons per year. But it is impossible to quantify all of them.

Of those pollutants whose sources in the U.S. have been quantified, lead, cadmium, arsenic, mercury, and polycyclic aromatic hydrocarbons have the largest emissions. For all of these, municipal waste incineration is a source; for lead, cadmium, and mercury, it is a major source. For lead, cadmium, mercury, and arsenic, coal combustion also is a major source, and motor fuel combustion produces large amounts of lead and cadmium. Because the number of municipal incinerators in the U.S. is expected to grow from about 100 to about 300 in the next few years, incinerators probably will become even more important sources of airborne toxics in the future.

Even though lead emissions have declined sharply over the past several years and are expected to decline still further, motor vehicles still emit 15,400 metric tons each year. Municipal waste incineration is the second largest source, at 2800 metric tons.

Annual total emissions of arsenic are also large—in the range of 3300 metric tons. The use of arsenical pesticides is the major source, with coal combustion a close second.

Mercury is an unusual pollutant in that the natural sources are as large or even larger than the anthropogenic. The National Academy of Sciences estimates that natural sources emit 1000 metric tons annually, whereas man-made sources produce 650 metric tons. The largest single man-made source is coal combustion followed by municipal waste incineration. One problem with incinerators is that as the operating temperature is increased to produce more complete combustion of organic pollutants, more mercury is volatilized into flue gases.

Polynuclear aromatic hydrocarbons, which are measured as BaP, are perhaps the most difficult critical pollutant to regulate because wood combustion in stoves and fireplaces is by far the greatest source. Agricultural burning and wildfires are secondary sources.

The emissions of those critical pollutants that are no longer being manufactured in the U.S., or were never produced there directly, are impossible to quantify and extremely difficult or impossible to regulate. But because many of these are very persistent and can still be measured in the air in the Great Lakes Basin, it is clear they are circulating through the environment.

For example, PCBs have not been manufactured for more than a decade, so present environmental releases come from PCBs in current use and from disposal sites. Releases result from fires, spills, and other accidents, and evaporation from landfills, where 140,000 metric tons are estimated to have been disposed of. The total amount of PCBs still in service in transformers and capacitors is about 340,000 metric tons.

Toxaphene, DDT, dieldrin, lindane, and mirex also are not now being produced in the U.S., and toxaphene and DDT are no longer being used. However, some fraction of the 550,000 metric tons of DDT and 320,000 metric tons of toxaphene used in the past is probably still cycling through the environment. Also, a part of the 11,000 metric tons of DDT used in Latin America each year may undergo atmospheric transport and deposition to the Great Lakes Basin.

Thus, barring a drastic change in lifestyle and the economy, such as banning woodstoves and coal and oil combustion, some airborne critical pollutants will continue to reach the Great Lakes. However, the amounts of some of those that become airborne can be minimized by use of catalytic converters on wood stoves, by better controls on municipal waste incinerators, by better control of flue gases from coal combustion, by the controlled incineration of all the PCBs now in use or storage, and by considering the consequences of evaporation when designing waste treatment systems. Pesticides such as DDT and dieldrin that are no longer produced in the U.S. but are used in Latin America are impossible to deal with except with an international accord.

Airborne emissions of some critical pollutants in the U.S. are extremely large

	Metric tons per year
Lead	21,305
Gasoline combustion	15,400
Municipal waste incineration	2,800
Industrial processes	2,300
Coal combustion	778
Other sources	27
Arsenic	3,332
Use of arsenical pesticides	1,500
Coal combustion	1,390
Primary copper smelters	312
Other sources	130
Mercury	1,668
Natural	1,019
Use of consumer goods	352
Coal combustion	132
Municipal waste incineration	68
Copper smelting	41
Sewage sludge incineration	36
Other sources	20
Polynuclear aromatic hydrocarbons	655
Wood combustion	560
Prescribed forest and agricultural burning	40
Wildfires	20
Gasoline combustion	13
Coal combustion	8
Other sources	14
Hexachlorobenzene	21–29
Pesticide use	17
Manufacture of chlorinated solvents	3–11
Other sources	1

Source: International Joint Commission

Hazardous waste sites

Reducing toxics that enter the Great Lakes from hazardous waste sites is nearly as complicated, or perhaps more complicated, and difficult to handle as airborne toxics. Toxics enter the lakes from landfills via surface water runoff, groundwater leaching, and volatilization and redeposition. There are 132 Superfund waste sites on the National Priorities List on the U.S. side of the Great Lakes Basin, and at least 10 major abandoned hazardous waste sites on the Canadian side. Contaminated surface and groundwater flowing from many of these finds its way into the lakes. None of the Superfund sites have been cleaned up completely.

In a three-mile strip along the U.S. side of the Niagara River alone, there are 164 toxic waste disposal sites. Of these, the U.S. Geological Survey has identified at least 57 that have a major potential for contaminant migration. According to Lindsay A. Swain, regional groundwater specialist with the USGS, a major man-made tunnel called the Falls Street tunnel is serving as a conduit so that 6 million gal of contaminated groundwater leak each day into the Niagara River gorge. A compact called the Toxics Management Plan and an associated Memorandum of Understanding have now been formed among the U.S., Canada, Ontario, and New York to clean up the waste sites and control municipal and industrial discharges along the Niagara River.

Even when a decision is made to clean up a Superfund site, dealing with the contaminated material so that it will not cause future environmental problems is difficult. If the material is merely removed from one site and placed in a so-called secure landfill with a liner, the liner eventually will fail. However, the contents of a Superfund site may be too large to be incinerated or treated any other way at a reasonable cost.

Similarly, active hazardous waste landfills that comply with current U.S. laws may present problems to future generations. Some of them are sited along the Great Lakes and rivers leading into them. When the liners fail, they too may require very expensive cleanup.

Swain points out that a large fraction of the basin is covered with outwash sand and gravel deposits. "These are usually very permeable and allow rapid vertical and horizontal flow of water and, if present, transport of any contaminants," he reports. Therefore, leachate from waste sites placed on these deposits could leak rapidly into the lakes.

Industrial discharges in both the U.S. and Canada have been reduced considerably. Many industries in the Great Lakes Basin on both sides of the border, however, are still not in compliance with their permits. In 1986, about 7% of major U.S. industrial plants in the basin and 44% of Canada's were out of compliance with the regulations on discharges. Another problem is that the discharge permits are primarily for the conventional pollutants such as suspended solids and toxic metals. Many other pollutants are unregulated. For example, the effluents from some hazardous waste treatment facilities contain as many as 300 chemicals, of which only 62 are regulated by EPA.

Several recent initiatives will help improve the situation. Ontario is developing a program called Municipal/Industrial Strategy for Abatement (MISA), which will require that industries use best-available technology treatment before discharging waste. The U.S. is implementing a pretreatment program for control of discharges from small concerns to municipal sewage systems. This has been a major defect in both the U.S. and Canadian programs for controlling industrial discharges because many small operations have been discharging directly into municipal sewage treatment systems. For example, in Ontario about 11,800 plants discharge into municipal sewers; only 154 plants are regulated.

During the process of Great Lakes cleanup, the greatest progress has been made through the upgrading of municipal wastewater treatment plants. Many old systems, however, still have what is called combined sewer overflows, in which storm water passes through the same pipes as sewage. During heavy rains, the volume is too great to be handled by the sewage treatment plant and storm water and untreated sewage overflow into a river leading to one of the Great Lakes or into the lake itself. Combined sewer overflows are a source of all kinds of contamination, including pollutants from small industrial concerns that discharge in sewage systems. Combined sewer overflows are a problem in nearly all the urban areas of concern. Michigan alone has at least 191 combined sewer overflows. Rochester, N.Y., is now spending $750 million to separate its storm water system from the main sewage system. Unfortunately, the cost of separating storm water pipes from the sewage system is more than some communities are willing to spend.

Because many of the critical pollutants for the Great Lakes, such as pesticides and PCBs, reside in soil and are strongly attached to soil particles, erosion from agricultural and urban land is a major source of toxics, especially for Lake Erie, which is bordered by intensely farmed and industrialized areas. This was first recognized in 1978 in a report prepared by the International Reference Group on Great Lakes Pollution from Land Use, a committee created by IJC to investigate urban and rural runoff. The levels of pesticides in urban runoff can be even higher than those in agricultural runoff, because the amount of pesticides used per acre on home lawns and golf courses is often higher than it is on farms.

Actions now being taken to reduce nutrient loadings from farmland also will reduce the amounts of pesticides that enter the lakes attached to soil particles. In addition, the government of Ontario is encouraging the use of integrated pest management, which minimizes the use of pesticides on farmland and therefore the amount entering the lakes.

Areas of concern

Perhaps the most positive development for the Great Lakes Basin that has taken place recently regards the 42 areas of concern. Twenty-five of these are in the U.S., 12 are in Canada, and five are in international waters under joint jurisdiction. Most of them are major municipal and industrial centers on Great Lakes rivers, harbors, and connecting channels, and in all of them the water quality is particularly degraded. Nearly all of them used to be plagued with bacterial pollution and eutrophication, but these conditions have been largely taken care of. Now, the major problem in 41 of the areas is persistent toxic substances.

A new process has been initiated for planning and implementing cleanup of these areas. Its development began in 1985, when the U.S. states and Ontario decided to create remedial action plans to restore beneficial uses such as fishing and swimming in all areas of concern within their boundaries.

What is different about remedial action plans is the

Public health agencies have issued advisories for consumption of certain Great Lakes fish

	Restrict consumption[a]	Do not eat
Lake Michigan	Lake trout 20 to 23 inches, coho salmon over 26 inches, Chinook salmon 21 to 32 inches, and brown trout up to 23 inches	Lake trout over 23 inches, Chinook salmon over 32 inches, brown trout over 23 inches, carp, and catfish
Lake Superior	Lake trout up to 30 inches, Walleye up to 26 inches	Lake trout over 30 inches, Walleye over 26 inches
Lake Huron	Lake trout, rainbow trout, and brown trout	—
Lake Erie	Carp and catfish (New York State waters—eat no more than one meal per month)	Carp and catfish
Lake Ontario	White perch, coho salmon up to 21 inches, rainbow trout up to 18 inches (eat no more than one meal per month)	American eel, channel catfish, lake trout, Chinook salmon, coho salmon over 21 inches, rainbow trout over 25 inches, brown trout over 18 inches

[a] Nursing mothers, pregnant women, women who anticipate bearing children, and children age 15 and under should not eat the fish listed in any of these categories.

way in which they are developed. According to the Water Quality Board, "Previously, separate programs for regulation of municipal and industrial discharges, urban runoff, and agricultural runoff were implemented without considering overlapping responsibilities or whether the programs would be adequate to restore all beneficial uses."

In contrast, a wide range of government agencies, local citizens, local environmental groups, and representatives of industry contribute to the development of remedial action plans. The theory is that only by involving all affected groups (called stakeholders) in the planning process will a workable cleanup plan be devised and financed. So far, public meetings to formulate remedial action plans have taken place in 32 of the 42 areas of concern.

Originally, the jurisdictions underestimated the time that would be required to develop remedial action plans and intended to submit all of them by December 1986. Now, most of the plans are scheduled to be completed by January 1990.

Contaminated sediments are a problem in 41 of the 42 areas of concern. These are a source of toxic inputs to the biota of the lakes. Pollutants adsorbed on the sediments can become biologically active by a variety of processes. Organisms living in the sediments can absorb or ingest pollutants and solubilize them. Wave action, particularly during storms, and currents can disturb sediments, releasing some of the toxics. Also, disturbances from shipping and dredging can release pollutants tied up in sediments.

Sediments are one of the most difficult problems to deal with because their volume is so large and U.S. experience in dealing with them is very limited. There are several ways sediments can be treated. They can be placed in confined disposal facilities next to or in the lake (a diked containment area), placed in a confined area inland from the lake, reused on land for agriculture or for quarry and strip mine reclamation, isolated and treated in situ, decontaminated after dredging, or placed farther out in the lake in open water.

None of these methods has been used very much except for placing the sediments in confined disposal facilities and dumping them farther out in open lake water. The major problem with confined disposal facilities is that water can wash off the sediments during heavy storms, carrying contaminants with it and sometimes removing fine sediments if the facility is not designed properly. In some jurisdictions, dumping contaminated sediment farther out in the lake is no longer acceptable because it is believed that many of the contaminants eventually will be released to the aquatic biota. During the next few years, EPA will fund several demonstration projects to try to determine the best ways to treat contaminated sediments.

Conrad Kleveno, director of bilateral relations for EPA's office of international affairs, expects the remedial actions plans to be implemented for all the areas of concern over the next five years. Then, he expects to see a "major reduction in chemicals throughout the lakes."

Because there are no objective criteria for listing or delisting an area of concern, it is difficult to tell how to designate certain areas. A jurisdiction, which can be a city, county, or state, nominates a restricted region as an area of concern, using the loss of beneficial uses as a criterion. IJC then designates the area as an area of concern. It has no power to place a region on the list without the consent of the jurisdiction, however. Some observers argue that many regions that have lost beneficial uses should be on the list, but have not chosen to be listed. Another problem is that the only criterion for taking a region off the list is the decision that beneficial uses have been restored. In other words, after cleanup procedures have been carried out, there is no measurable way to tell if the area is clean enough.

A long, difficult process

Though the Great Lakes cleanup effort has made substantial progress since it was first initiated in 1972, solving the problem of persistent toxic substances will probably take many years. The basin is affected by a wide variety of sources of contaminants from both inside and outside the basin and a wide variety of environmental laws and regulations in both Canada and the U.S. Therefore, the toxics problem likely will never be addressed except in a piecemeal, temporary fashion unless people outside the basin, as well as the population within it, take an active interest in protecting it.

Some have suggested that the only way to ensure the continued health of the lakes is to eliminate inputs of persistent toxic substances into the lakes almost entirely. They advocate a change in lifestyle—a new way of thinking beginning in the home on a personal level. They urge people to consider what effects the products they buy may have on the environment—in their manufacture, use, and in the disposal of unused portions.

Such an approach could help in the cleanup effort. However, it also could lead the public to concentrate on single chemicals that are well-known pollutants to the exclusion of other, lesser-known substances that may be causing more damage—such as polycyclic aromatic hydrocarbons from woodstoves or cadmium from coal burning. Because society cannot control all pollutant sources completely, rational choices will have to be made between them and about the degree of control that is most desirable. The Water Quality Board expects public anxiety toward the effect of persistent toxic pollution to continue to grow. "This effect could represent a kind of 'microchemophobia' with the result that rational decisions could be compromised and significant resources could be misdirected to the wrong problem," the board says. □

Reprints of this C&EN special report will be available in black and white at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.

A1250-1
2/19/88

FEBRUARY 15, 1988

CHEMICAL & ENGINEERING

NEWS

0511179C098 9 K AR66075L 1*DG
CONGRESSIONAL INFO SERV-SRI3DG
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Nuclear Weapons Testing

Should it be banned?
Page 8

CHEMICAL & ENGINEERING NEWS

Volume 66, Number 7
CENEAR 66 (7) 1–70
ISSN 0009-2347

FEBRUARY 15, 1988

News of the Week

- **Competition to decipher the structure of a new class of superconductors heats up.** **Page 4**
- **Alberta-based Nova Corp. ups its offer for Polysar Energy & Chemical Corp. in Ontario.** **Page 5**
- **NRC urges multiagency federal effort to precisely map the complete genetic code of humans.** **Page 5**
- **Controversy persists over U.S. Patent & Trademark Office's decision to grant patents on new forms of animal life.** **Page 5**
- **New British collaborative research programs will be funded equally by industry and government.** **Page 6**
- **Outcome of clean air bill uncertain as it reaches House subcommittee markup vote.** **Page 6**

Cover: Signal cables are laid out at nuclear weapons test facility at Yucca Flat, Nev., before being lowered into test hole (beneath tower) with weapons canister. Photo courtesy of Department of Energy

Letters 2
Editor's Page 3

Concentrates

Business 19
Government 23
Science/Technology 27

The Departments

New Products 41
ACS Focus 42
ACS News 43
Awards 45
Meetings 48
Newscripts 70

Business

Du Pont Canada supports U.S.-Canadian free trade agreement, believes the pact will foster the development of market opportunities in the U.S. **Page 21**

Small U.S. company, Diversified Tech, is successfully marketing Soviet polymer technology to repair serious bone breaks. **Page 22**

Government

Nearly all Presidential candidates put key elements in competitiveness, such as capital formation and science and technology, among top priorities. **Page 24**

NSF director Erich Bloch's suggestion that the agency end support for high-energy physics research triggers strong reaction from the federal science community. **Page 26**

Technology

Monsanto's use of genetic engineering to improve heritable crop resistance to insect pests, viruses, and herbicides shows some promising results in field tests. **Page 28**

News Focus

Debate heats up over continued nuclear weapons testing and over the long-smoldering issue of implementing an agreement to either stop testing or put it under tighter control. **Page 8**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)
News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman*: Ernest L. Eliel; *President*: Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Director, Business Management Division, ACS, P.O. Box 57136, Washington, D.C. 20037. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 69)

LETTERS

Waste in space

SIR: I am writing to draw the attention of C&EN readers to a statement by Jacques Cousteau in his December 1987 Calypso log, in which he expresses his apprehension of the Strategic Defense Initiative program.

Cousteau points out that the antisatellite testing that the U.S. has already started is littering space with thousands of small fragments traveling at a speed of Mach 20—10 times the speed of the Concorde.

He describes "this latest fad in military technology . . . destroying military satellites and intercontinental missiles with laser beams" as "yet another distressing example of our criminal inability to manage the progress of technology."

His dire conclusion: "If we do not take action, this waste will become an almost impenetrable shield which could prevent, perhaps for a thousand years, our access to space. Ironically, it is the conquest of space itself, handled in a way that defies common sense, that could nail us definitively to Earth."

Alan Rhodes
Willoughby, Ohio

Alcohol in gasoline

SIR: I just became aware of Donald F. Othmer's letter on methanol to gasoline (C&EN, Nov. 30, 1987, page 2), and feel that I should offer some rebuttal.

It is true that I spent 32 years with what is now Exxon at Baytown, Tex., but I retired involuntarily in 1971 as a result of a large reduction in research funding. I spent the next 10 years at the University of North Dakota, first as project manager of Project Lignite, and then as principal investigator and adjunct professor of chemical engineering.

With regard to Othmer's reference to E. E. David, it is certainly true that methanol is "the lowest-cost liquid available from coal" if indirect liquefaction is the only process considered for coal conversion. Of course Exxon Research has done extensive and apparently successful work on the direct liquefaction of coal to produce liquid hydrocarbon fuels. This work came to an end as a result of the lowering of OPEC crude oil prices.

The problems caused by alcohol in motor fuels are well recognized in the Midwest, where a number of service stations advertise: "Our gasoline contains no alcohol." The stations selling motor fuels that contain alcohol either do not advertise it or mention it in small print as required by law. The reason for alcohol in the motor fuels is the subsidies supplied by the U.S. and by some farm states for the use of agricultural alcohol.

I know that methanol is the fuel of choice for high-performance engines, where fuel economy and engine life are not the primary considerations as long as the vehicles can finish the race. As I mentioned before, I have and would use such a fuel in these circumstances. However, I was somewhat surprised by the claim of greater safety, since methanol has much wider flammability limits than the hydrocarbons used in motor fuels. Further, it burns with a very clean nonluminous flame, which has resulted in burns to pit crewmen who inadvertently approached too close to flames in a fire during a pit stop. This was dramatically illustrated some years ago during a televised Indianapolis 500.

I do not have access to the article referred to by Othmer on the fuel test, but it is not surprising that the alcohol blend gave equivalent or slightly greater fuel economy than the straight gasoline if no changes were made in the engine. Conventionally carbureted gasoline engines are usually set to run slightly rich to ensure that an adequate mixture reaches the more distant cylinders. The result of adding the methanol, in addition to increasing octane number and reducing the tendency to knock, would be to lean the mixture at the same fuel-to-air ratio and improve efficiency somewhat. The same sort of result might be obtained by water injection, and indeed devices for that are advertised in some publications. Efficiency could also be improved with the gasoline fuel by increasing the octane number and leaning the mixture.

The folks advocating the use of alcohol are attemptimg to accomplish this by political means, as in the attempt in the California legislature. This reminds me of the old saying: "Technology tells us what can be done. Economics tells us what should be done. Politics tells us what will be done."

A. M. Souby
San Marcos, Tex.

Correction

- Feb. 1, page 39: In the listing of Toronto hotels and their rates for the 3rd Chemical Congress of North America/195th ACS national meeting, the exchange rate between the U.S. and the Canadian dollar was inverted. The correct rate is $1.00 U.S. equals about $1.27 Canadian.

Nuclear Weapons Testing

Issue of further testing constraints reignites in wake of shifting U.S. and Soviet attitudes

NEWS ANALYSIS

Michael Heylin, C&EN Washington

Ever since the first nuclear test explosion 43 years ago, there have been efforts to ban, or at least constrain, such tests. Such efforts have been spotty and have met with only modest success.

For 25 years there have been treaty limits on where tests can be conducted: They must be underground. For 12 years there have been limits on their size: not larger than the equivalent of 150 kilotons of TNT. But these constraints have done nothing to hamper development and deployment of new nuclear weapons systems. There are no treaty limits on the number of tests and they go on unabated. Last year there were 47 worldwide. The long-term average is 42 per year.

That first nuclear blast, which brightened the early morning sky near Alamogordo, N.M., on July 16, 1945, has been followed by more than 1750 nuclear explosions conducted by at least six nations.

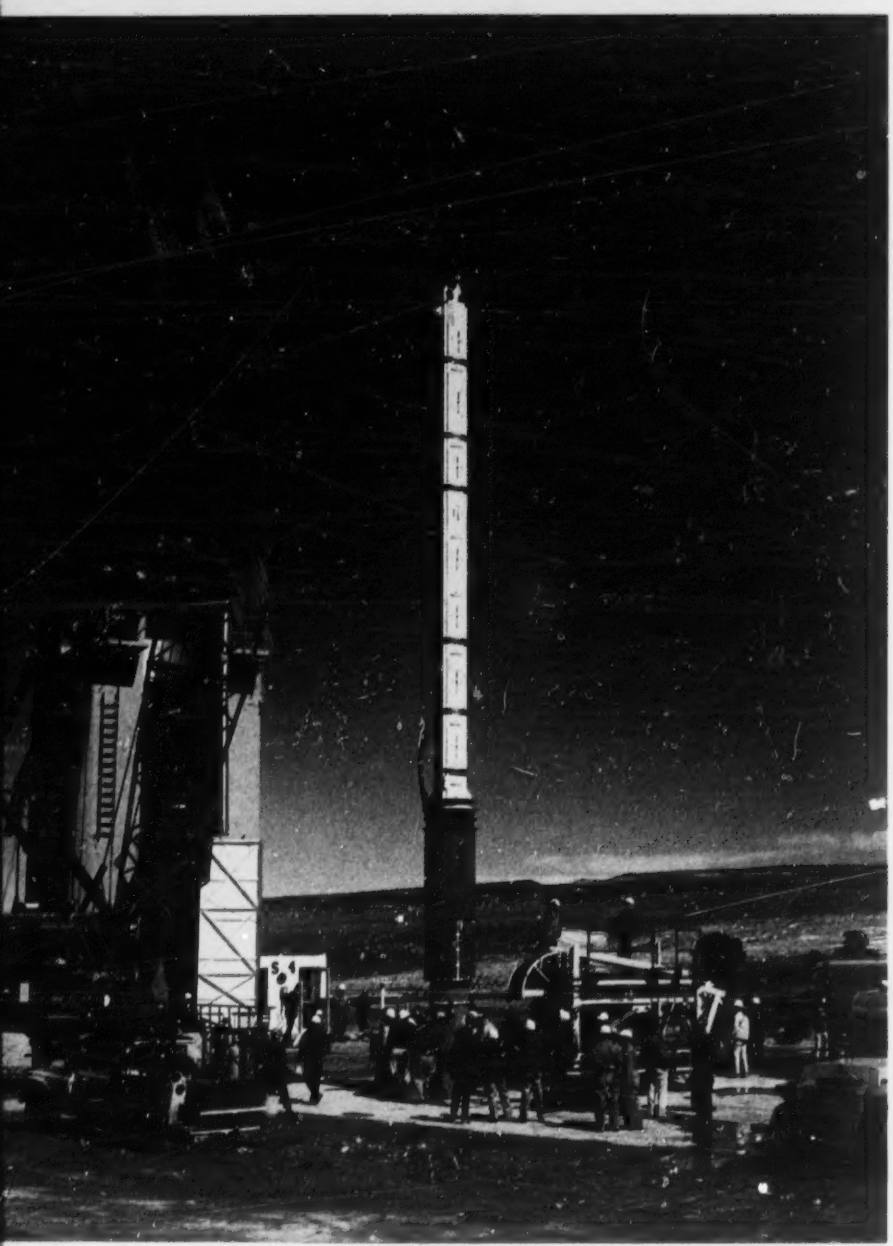
Nuclear testing has long had the characteristics of a major, established business. The Nevada Test Site, the location of all current U.S. tests, has been in operation since 1951. It covers an area bigger than Rhode Island. With 8500 employees, it has the largest payroll in Nevada. Its annual budget is approaching $1 billion.

The Soviet Union's primary test site, in Kazakstan, near Semipalatinsk, is of similar dimensions. The French have a major testing facility at Mururoa in the South Pacific. The Chinese have a testing operation in Xinjiang. The British test their weapons at the Nevada Test Site under a cooperative agreement with the U.S. The only other nation known to have conducted a test is India, with just one, in 1974.

Despite this seeming inevitability of continued nuclear weapons testing, the issue of a ban that would either stop it altogether or put it under much tighter control has been a focus of intense and growing contention in this country and abroad.

Both sides in this debate agree on one thing—that a comprehensive ban on all testing or a ban on all tests above a low threshold, such as 1 kiloton, would prevent the development of new nuclear weapons systems, including so-called third-generation, directed-energy weapons. For those who favor continued reliance on technology in defense matters, this is anathema. For those who seek constraints, it is the very purpose of an agreement.

The issue has been marked by shifts in attitude by the superpowers in recent times. The Reagan Administration sees a comprehensive test ban only as a very long-term goal for the U.S. It says that even more modest limits on testing can come only in step with a long process of nuclear arms reductions and that a comprehensive ban would be appropriate only when nuclear deterrence no longer underpins national security. Another new factor has been the need for nuclear testing in support of the Strategic Defense Initiative launched by President Reagan in March 1983 and now the cornerstone of U.S. defense policy.


Department of Energy photos

A nuclear device and diagnostic canister are lowered down an emplacement hole prior to testing at Pahute Mesa in the northwest corner of the Nevada Test Site, the location for higher-yield tests

The Soviets, on the other hand, have been pushing extremely hard lately for a ban on all testing. They have become more accommodating concerning adequate mechanisms, such as on-site inspections, for monitoring such a ban. They have allowed U.S. scientists to install and operate seismic monitoring equipment on their territory. And they unilaterally halted their own testing from August 1985 to February 1987 and state they would stop testing again "tomorrow" if the U.S. also would stop.

But after a hiatus of eight years the superpowers are at least talking to one another again at the diplomatic level about nuclear testing. What are formally known as Nuclear Testing Talks were opened last fall in Geneva. The first order of business is working out details of a joint verification experiment in which teams of experts from each side will work together to measure nuclear explosions at Nevada and Semipalatinsk.

The Department of Energy, the agency responsible for developing and producing nuclear weapons, sees a comprehensive test ban as ill advised at this time. The department argues that as long as the U.S. relies on nuclear weapons for deterrence, it must have the right to test them to assure the reliability of the stockpile, to keep current weapons systems up to date and safe, to develop new ones, and to test the effects of radiation on military equipment.

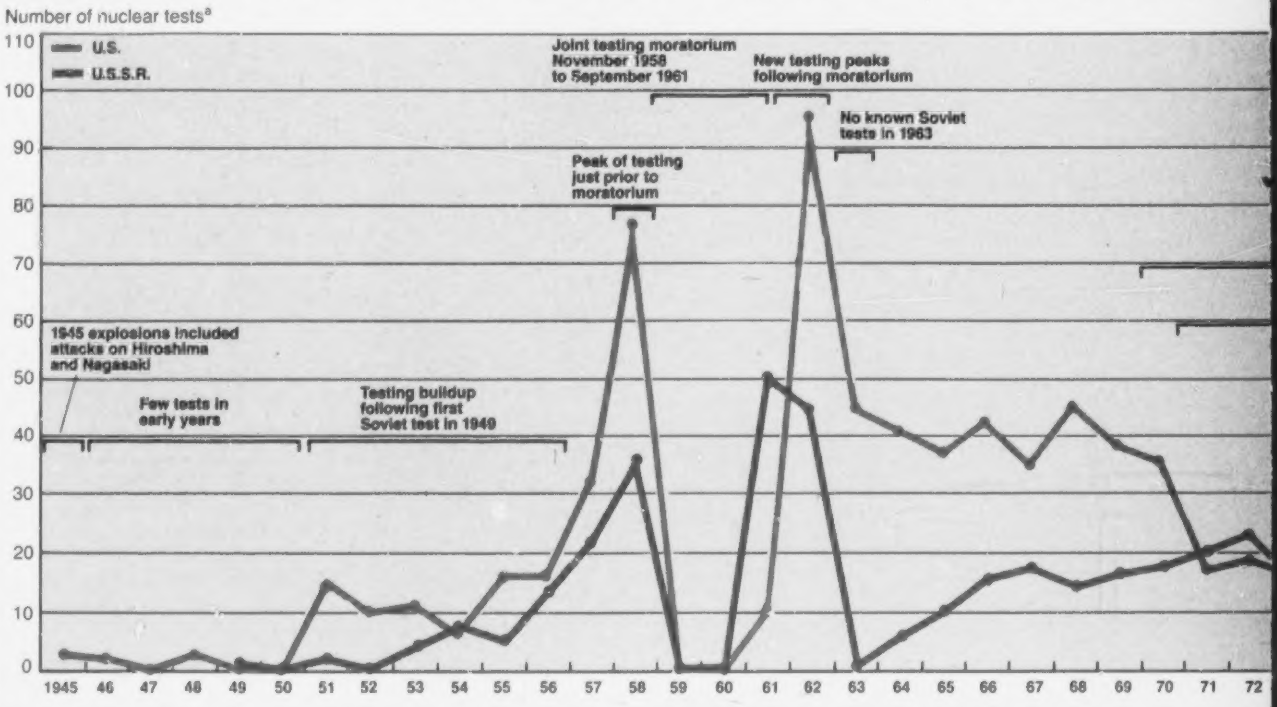
Proponents of a testing ban argue that the continuous modernization of nuclear arsenals brings not enhanced security, but greater danger and instability. They also insist that the reliability of weapons in today's stockpile can be assured adequately without continued nuclear testing.

Another argument concerns the monitoring of testing limits. The Administration contends that the Soviets have likely violated the 150-kiloton limit, and that even this 150-kiloton level cannot be monitored with confidence. Proponents contend there is no unambiguous evidence of Soviet violation of the 150-kiloton provision. And they argue that modern seismic methods, backed up by other intelligence-gathering assets, are adequate for monitoring testing threshold far below the current 150 kilotons.

The role of Glenn T. Seaborg

A chemist who has been at the center of all these issues for almost three decades is Nobel Laureate Glenn T. Seaborg. He headed the Atomic Energy Commission, the agency then responsible for nuclear weapons, from 1961 to 1971.

U.S. and Soviet Union have conducted between them about 1500 nuclear tests over past 43 years



[a] Annual totals include defense-related tests and so-called peaceful nuclear explosions (PNEs). **Sources:** Natural Resources Defense Council, Department of Energy

As head of AEC, Seaborg was involved in the negotiations with the Soviet Union and the U.K. that led to the signing of the Limited Test Ban Treaty (LTBT) in Moscow on Aug. 5, 1963. This agreement bans tests in the atmosphere, in space, and underwater. Only an impasse over the number of obligatory on-site inspections prevented this treaty from being comprehensive by also banning underground testing. Seaborg thinks that the U.S. was wrong in 1963 in its insistence on the on-site inspections issue. His view is that the world would be far better off if the treaty had banned all testing. He remains an active advocate of a comprehensive test ban (CTB) and was keynote speaker at a conference on nuclear testing issues just last month in Las Vegas.

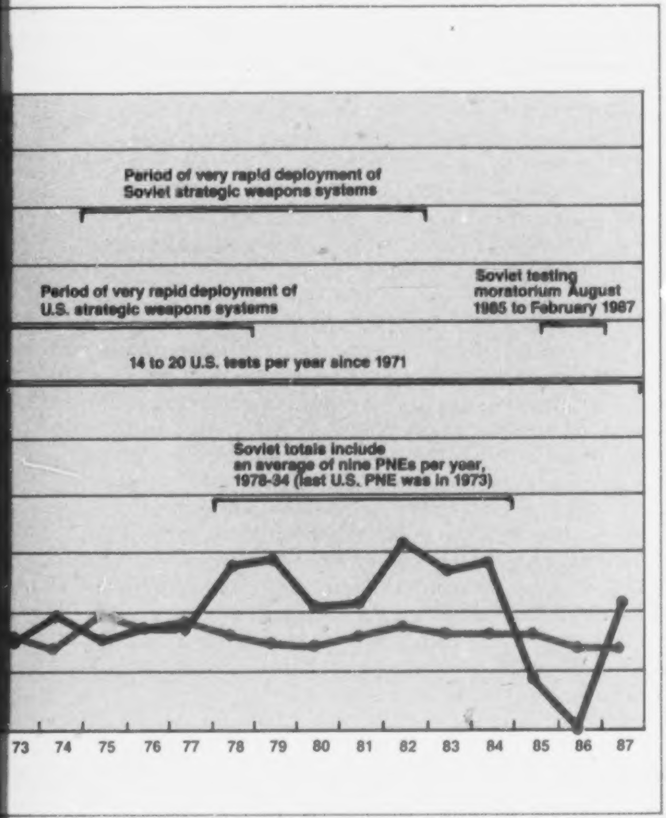
A former president of the American Chemical Society, Seaborg articulated his views in a letter published in the June 13, 1983, issue of C&EN. He stated that, "A CTB would halt that aspect of the arms race that is most threatening, the qualitative improvement in nuclear weapons. Such improvements in offensive weapons continue to make them ever more dangerous. Improvements in defensive weapons might tempt either side to launch a first strike on the assumption this can be done with relative impunity or needs to be done before the other side achieves an effective defense."

Seaborg's letter triggered considerable interest among ACS members and, incidentally, became something of a hot potato for the staunchly apolitical society. The ACS Board of Directors defeated a motion that it support a CTB by a vote of 10 to four. But a number of local sections called for at least a discussion of the issue. After the matter had been bounced around the society for some time, Ellis K. Fields, ACS president in 1985, made nuclear testing the subject for his presidential plenary session at the society's national meeting in Chicago in the fall of that year.

In his address in Las Vegas, Seaborg said he is certain that President John F. Kennedy and Nikita Khrushchev would have followed up on the treaty's charge to its signatories to continue negotiations to "achieve the discontinuance of all test explosions of nuclear weapons for all time." But within just over a year of the signing of the treaty Kennedy was dead and Khrushchev out of power.

The history of testing

Like Kennedy, President Dwight D. Eisenhower worked actively for nuclear testing constraints. And he might have reached an agreement if U.S.-Soviet relations had not soured in 1960. But he was instrumental in the nuclear test moratorium that started in November 1958. This total pause in U.S. and Soviet testing ended after almost three years on Sept. 1, 1961, when the Soviets, without prior announcement, started a major program of tests in the atmosphere. By year's end, they had conducted about 50 tests. The U.S.



resumed testing 14 days after the Soviets. By the end of 1961, it had conducted 10 low-yield underground tests at the Nevada Test Site. On April 24, 1962, the U.S. started a program of atmospheric tests at Christmas Island and other Pacific locations that went on all year. The U.S. conducted a record total of 96 tests in 1962. Since 1971, U.S. and Soviet weapons testing programs each have settled down to an average of between 15 and 20 such tests per year.

Since 1976, U.S. weapons tests and, according to most experts, probably all Soviet tests have been within the 150-kiloton framework spelled out in a bilateral agreement, the Threshold Test Ban Treaty (TTBT), signed by President Richard M. Nixon and Leonid Brezhnev in Moscow on July 3, 1974. A similar 150-kiloton limit was placed on so-called peaceful nuclear explosions as a result of another treaty, the Peaceful Nuclear Explosion Treaty (PNET), signed in Moscow by Brezhnev and President Gerald R. Ford in 1976.

Unlike his predecessors, President Jimmy Carter never got to sign a nuclear testing agreement. On coming to office, Carter made no effort to push for Senate ratification of the TTBT and the PNET. Instead, Carter pushed for a comprehensive treaty in negotiations that opened in the fall of 1977. Agreement in principle was reached on such previously touchy issues as in-country seismic monitoring stations and on-site inspections. But many important details remained unresolved and in the end Carter decided that the inevitable controversy that would erupt in the Senate over ratification of a test ban treaty would likely endanger the SALT II agreement, the centerpiece of his arms control program.

The case for testing

One of the most articulate spokesmen for continued testing is George H. Miller, associate director for defense systems at Lawrence Livermore National Laboratory, the organization, which, along with Los Alamos National Laboratory, is responsible for developing nuclear weapons.

In an address at last year's annual meeting of the American Association for the Advancement of Science entitled "Avoiding Nuclear Escapism," he stated that, "For the foreseeable future the stability of the strategic balance and the security of the nation will depend on nuclear weapons. Our ability to maintain the stability of the present deterrent depends in an intimate way on our ability to continue to test nuclear weapons." He went on, "We should not delude ourselves into thinking that a nuclear test ban would enhance the safety of our country. It may, in fact, do quite the opposite. A comprehensive test ban may be the correct last step in our quest for nuclear arms control and a stable peace. But it would be a disastrous first step for the U.S. to take."

He also pointed out that nuclear testing has enabled the U.S. to reduce its stockpile of strategic and tactical nuclear warheads some 25% from its peak in the late 1960s and to cut its total destructive force about 75%.

What Miller did not point out, however, was that the number of U.S. strategic warheads has grown from about 4000 in 1970 to about 11,000 today, while the Soviet strategic arsenal has increased from about 2000 warheads to about 10,000. Continued testing also has allowed deployment by both sides of missiles with accurate multiple warheads—the very weapons

C&EN staff photo

Seaborg: stop qualitative improvements

This crater, the largest on the Nevada Test Site, was formed in July 1962 in a test of the effectiveness of nuclear explosions for massive earth excavation. The test involved a 100-kiloton device, buried 635 feet deep

that have caused the perceived "window of vulnerability" of such concern to the current Administration and the spur for the modernization of the U.S. arsenal in recent years.

The verification issue

The contention that nuclear testing is still needed for the development of new weapons systems is not amenable to technical dispute and analysis. It is a matter of defense policy, a purely political issue. But the claims that nuclear testing constraints cannot be adequately monitored and that the reliability of the current stockpile is dependent on continued testing have generated heated technical discussion.

The Administration's claim that the Soviets have likely violated the 150-kiloton provision of the 1974 treaty has been particularly hotly disputed, and not only by those outside the defense establishment.

The U.S. monitors this treaty through a worldwide network of seismic instruments known as the Atomic Energy Detection System. This teleseismic method involves measurement of the vibrations triggered in the Earth and along its surface by nuclear explosions.

The U.S. has not been able to calibrate the Semipalatinsk test site against test explosions of known size. Extensive data calibrating the Nevada Test Site have not been particularly useful because of the difference in geology between Nevada and Semipalatinsk. Geologically the Soviet site is older and harder than Nevada. When Soviet tests are measured seismically they appear larger than Nevada tests of the same size unless an appropriate "fudge" factor is used. The argument has been over how large this factor should be.

The Administration continues to rely on a factor that indicates the Soviets have exceeded the 150-kiloton limit more times than the treaty allows under a so-called "whoops" clause, which allows for the uncertainty of yield measurements.

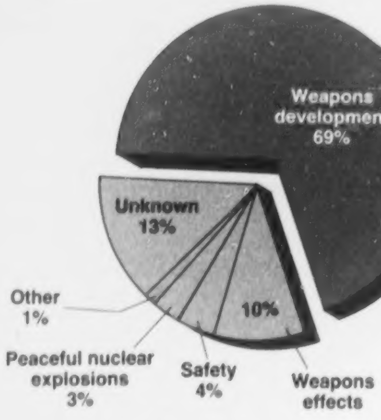
Miller told the AAAS meeting that Lawrence Livermore believes that the Soviets have complied with the treaty, although it cannot be sure there haven't been a few tests above 150 kilotons. In 1986 the Central Intelligence Agency revised its estimate of the size of Soviet tests downward by 20%. And government witnesses before a hearing of the House Permanent Select Committee on Intelligence last September did not support the charge of Soviet violations.

The committee's report, dated Nov. 19, states that, "National nuclear laboratory scientists noted that U.S. and Soviet tests exhibit a remarkably similar distribution in the number of tests now appearing to be above 150 kilotons. The executive branch characterization of Soviet behavior as a 'likely' violation is questionable and deserves re-evaluation."

However, the Administration has hung tough on this issue of monitoring. It insists the teleseismic method is just not good enough for adequate verification. It says that this method has an uncertainty factor of 2.0 at the 95% confidence level. This means that there is a one-in-40 chance that a test measured at 150 kilotons was actually more than 300 kilotons. Soviet scientists claim that the uncertainty factor is well below 2.0 and adequate for verification.

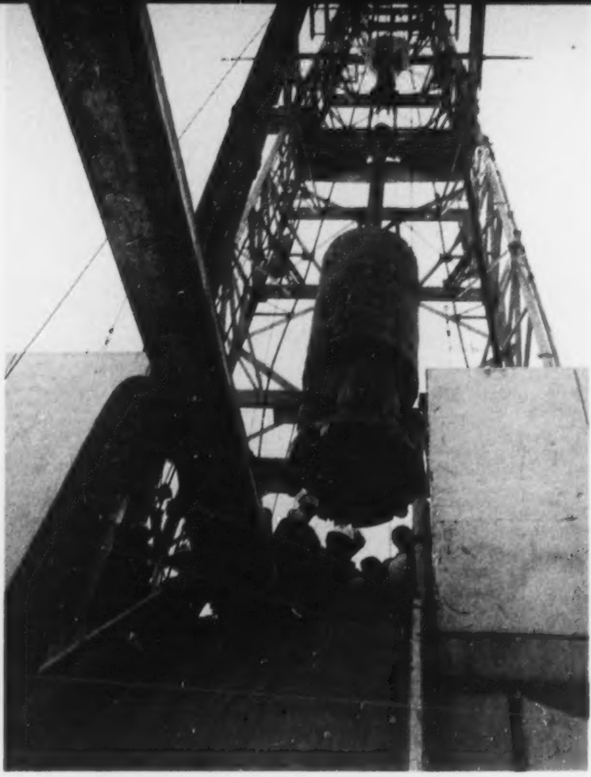
For some time the Administration has been propos-

Most U.S. tests are for weapons development



Total tests = 899ª

ª Through 1987 **Source:** Natural Resources Defense Council

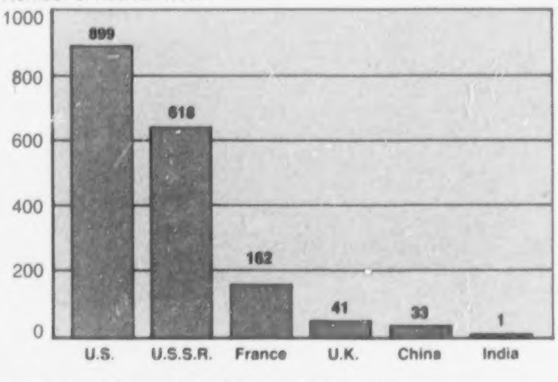


Underground nuclear tests are conducted in emplacement holes up to 12 feet in diameter and 5000 feet deep drilled by special large-diameter bits. Bits and steel collar above may weigh more than 200 tons

ing a hydrodynamic method for monitoring the TTBT. It invited the Soviet Union to send experts to the Nevada Test Site to observe a demonstration of this technique. At first the Soviets refused, wanting to leapfrog the issue of TTBT verification and move directly to negotiations on a comprehensive test ban that involves monitoring at much lower levels.

The Administration has prevailed. Last September Secretary of State George P. Shultz and Soviet Foreign Minister Eduard Shevardnadze announced agreement on stage-by-stage negotiations on nuclear testing. The first step is to agree on verification methods for the TTBT and the PNET. The next step will be negotiations on intermediate testing limitations. The third will be consideration of a comprehensive ban.

U.S. has conducted half of all nuclear tests since 1945, the Soviets one third



a Through 1987. **Source**: Natural Resources Defense Council

The hydrodynamic method being proposed is known as CORRTEX, an acronym for Continuous Relectometry for Radius versus Time Experiment. It involves the placement of a cable, attached to an electrical unit and a microcomputer on the surface, in a satellite hole about 45 feet from the emplacement hole holding the nuclear device. When the device is exploded the cable is crushed and short-circuited by the shock wave. The speed with which this crushing moves up the cable is measured by the electrical unit and the results translated into an estimate of yield.

The Administration claims that CORRTEX has an uncertainty factor of 1.3 or less. But the method has some drawbacks. First, there are not a lot of data on it. It has been used at the Nevada Test Site more than 100 times with the cable down the emplacement hole, but only four times using a satellite hole. Second, the Soviets claim its uncertainty factor would be higher than 1.3, and not significantly better than the teleseismic method, when conducted by a second party without total knowledge of the device being tested. Third, it would be very intrusive as those conducting the test would have to be on site. And, fourth, adopting it would involve a major revision of the TTBT.

In addition, the intelligence committee report states that, "Given the current U.S. capacity to monitor a 150-kiloton threshold, and emerging research on improving U.S. yield estimation techniques, continued executive branch insistence on additional specific verification methods for the TTBT and PNET before they are ratified is debatable."

Despite these problems and criticisms, plans are going ahead to use CORRTEX in the joint tests at Nevada and Semipalatinsk later this year. Teams of 20 Soviet and U.S. experts made familiarization trips to the two sites last month. This week they reconvene in Geneva to start working out details for the tests.

An Arms Control and Disarmament Agency official on the U.S. team tells C&EN that the aim of the tests is for each side to convince the other of the feasibility and adequacy of its "preferred" verification method: CORRTEX for U.S. and seismic for the Soviets. He stresses that the effort so far has been very cooperative and both sides are anxious to have the TTBT and PNET quickly ratified. The test blasts will be a little below the 150-kiloton level. The first could be as early as May, possibly the one at Semipalatinsk, with the Nevada test following later in the year.

Joint testing

The joint experiment planned for this year represents an unprecedented degree of cooperation by the U.S. and Soviet defense establishments. However, to its critics, it represents a lengthy digression from what they perceive as the more important issue of working toward either a comprehensive or a much reduced threshold treaty. The Soviets have been cooperative in this endeavor, too. But in this case with a private

Yucca Flat within the Nevada Test Site is the location of most current underground nuclear weapon tests. It is dotted with more than 200 craters formed by subsidence following such tests

organization, and somewhat at the displeasure of the Administration.

Since 1986 the Soviet Academy of Sciences and the Natural Resources Defense Council, a Washington, D.C.-based group, have been conducting a joint seismic project with the aim of demonstrating that verification is not an obstacle to a nuclear test ban or moratorium.

NRDC scientists have been manning seismic stations near the Semipalatinsk site since September 1986. This year the network of three stations will be increased to five and relocated about 600 miles from the site in order to focus on research on what would be needed to verify a 1-kiloton test limit nationwide. The stations have not been allowed to measure actual Soviet tests since the Soviets renewed testing a year ago. The Soviets insist they are turned off during tests. But the stations have been used to measure three chemical explosions of known size and they will be allowed to measure Soviet nuclear tests once they are relocated. Similar seismic stations have been established near the Nevada Test Site. And test chemical explosions are planned for later this year.

U.S. officials have tended to play down the significance of the NRDC project. They stress that it is not helpful to have a private group involved directly with the Soviets in such matters. NRDC personnel, on the other hand, feel that their effort may have helped to get the U.S. government off dead center.

Monitoring a comprehensive or low-threshold test ban is a far more formidable task than monitoring a 150-kiloton limit. The intelligence committee report states, "Monitoring a CTB would present a major technological and management challenge to the U.S. intelligence community. The deployment of a comprehensive monitoring capability for a CTB would require several years and hundreds of millions of dollars not currently programed by U.S. intelligence."

One of the few consensuses on this complex issue is that, technically, a monitoring system can be as good as negotiators would want to make it with in-country seismic stations, in-country radiation monitors, satellite surveillance, mandatory on-site inspection, data exchanges, and other cooperative measures. But no system could ever guarantee zero nuclear explosions. The key issue is how good it would have to be to give acceptably high confidence that the other side could not conduct a clandestine testing program of military significance.

There is little disagreement that any nuclear explosion above 15 kilotons can readily be detected and distinguished from earthquakes with current teleseismic means. Advocates of a testing ban, such as seismologists Lynn R. Sykes of Columbia University and Jack F. Everden of the U.S. Geological Survey, have long argued that a 1-kiloton detection level could readily be reached.

But two issues are constantly raised concerning the reliability of a test ban. One is the problem of differentiating small clandestine tests from literally thousands of small earth tremors and industrial chemical explosions. Test ban advocates respond that the large majority of small earthquakes could readily be identified as such because they occur under the oceans or at depths too great to be nuclear tests. Most industrial explosions could be confirmed from their location. The remaining uncertain incidents could be checked by satellite or other means or, as a last resort, by on-site inspection.

The other major issue is that of decoupled nuclear explosions. These are explosions set off in large underground caverns. This would reduce the vibrations they would cause and reduce their apparent size, when measured seismically, by a factor of 10 or more.

However, according to Jeremy K. Leggett of the Royal School of Mines in London, decoupled explosions have their drawbacks for potential evaders of a test ban agreement. He discussed what he calls the "evasion gauntlet" that a clandestine testing program would have to run at the Las Vegas meeting last month.

He pointed out that nuclear explosions of much less than 1 kiloton have been distinguished teleseismically more than 4000 km from their source. Under a treaty, a clandestine testing program would have to deceive in-country monitors at much shorter distances.

Leggett, who has studied the monitoring issue for many years, also points out that very little is actually known about decoupled nuclear explosions. The U.S. has conducted only one such test. There is also the problem of the availability of suitable caverns. They have to be the right size and shape and the right depth. Also they must not allow the release of readily detectable radioactive debris to the atmosphere. If man-made, such caverns would involve major, and hence potentially detectable, engineering projects. Also such caverns are most easily constructed, and more likely to occur naturally, in areas of salt strata. Such areas in the Soviet Union are reasonably well-known and would likely be closely monitored by in-country seismic stations. Also such areas are relatively quiet seismically. Hence any nuclear test would be more likely to cause suspicion.

The reliability issue

The argument over the need for continued nuclear testing to assure confidence in the reliability of warheads in the current U.S. stockpile hinges largely on classified data. The public is left to decide which of the very conflicting views expressed by weaponeers with current or recent access to the secret data to believe.

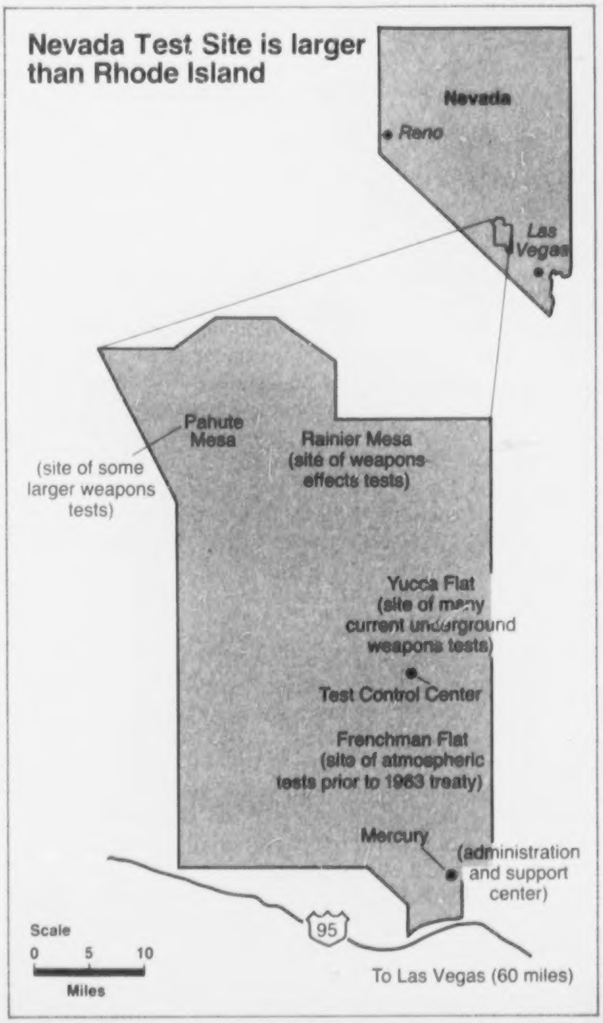
Lord Solly Zuckerman, a former long-time chief science adviser to the British government, expressed this dilemma best a few years ago when he wrote that the men in the nuclear weapons laboratories of both sides "have become the alchemists of our time, working in secret ways which cannot be divulged, casting spells that embrace us all."

However, both Congress and the science community have found ways to raise the central question of why the weapons labs insist that testing for weapons reliability is still essential, 25 years after the U.S. formally committed itself to negotiate an end to all weapons testing for all time.

In March last year Rep. Les Aspin (D.-Wis.), chairman of the House Armed Services Committee, and five other members of Congress asked Roger Batzel, director of Lawrence Livermore, to allow Ray E. Kidder, a veteran physicist at the lab, to prepare an independent review of the need for so-called proof testing of the current stockpile. Kidder had earlier published a critique of a study by a DOE contractor on the issue. Batzel agreed. He also had associate director Miller prepare a parallel report. Both reports were released in October.

Kidder's major conclusion was that, "A high degree of confidence in the reliability of the existing stockpile is justified, and that it is sufficiently robust to permit confidence in the reliability of remanufactured warheads in the absence of nuclear explosive proof-tests." He also contested the laboratory's claim that continued testing is needed because 14 of 41 warheads placed in the stockpile since 1958 needed such testing to assure their reliable operation.

According to Kidder, the experience with these 14 weapons "has little if any relevance to the question of maintaining the reliability of nuclear weapons that exist in 1987." He says nine of the 14 were weapons deployed just before or during the 1958–61 moratorium and, hence, were inadequately tested prior to deployment. He also claims that the postdeployment tests of the remaining five systems would not have been needed if they had been subjected to the more rigorous standards of nuclear testing now routine.



Nevada Test Site is larger than Rhode Island

Nevada
Reno
Las Vegas
Pahute Mesa
(site of some larger weapons tests)
Rainier Mesa (site of weapons effects tests)
Yucca Flat (site of many current underground weapons tests)
Test Control Center
Frenchman Flat (site of atmospheric tests prior to 1963 treaty)
Mercury
(administration and support center)
95
Scale
0 5 10
Miles
To Las Vegas (60 miles)

A history of nuclear testing and efforts to control it

1945—First nuclear test at Alamogordo, N.M.
—Attacks on Hiroshima and Nagasaki.
1947—Unsuccessful efforts to place nuclear matters under international control.
1949—First Soviet nuclear test.
1952—First British nuclear test.
1954—Increasing worldwide concern over health effects of nuclear testing in the atmosphere.
1958—Start of U.S.-Soviet moratorium on nuclear testing.
1960—First French nuclear test.
1961—Renewal of testing by Soviet Union, then by the U.S.
1962—Record 96 tests by the U.S.
1963—Limited Test Ban Treaty (LTBT) signed by U.S., Soviet Union, and U.K. and ratified by U.S. Senate (banned all but underground testing).
1964—First Chinese nuclear test.
1968—Nuclear Nonproliferation Treaty signed, committing nuclear powers to negotiating in good faith to end nuclear arms race at an early date.
1969—Nuclear Nonproliferation Treaty ratified by Senate.
1974—Threshold Test Ban Treaty (TTBT) limiting tests to 150 kilotons signed by U.S. and Soviet Union. (Both sides claim to have abided by this treaty, which has not yet been ratified by the Senate.)
—First and only Indian nuclear test.
1976—Peaceful Nuclear Explosions Treaty signed (not yet ratified by Senate).
—TTBT went into effect.
1979—U.S.-Soviet negotiators make progress toward a comprehensive test ban treaty (CTBT).
1980—CTBT talks suspended following Soviet military action in Afghanistan.
1982—U.S. formally breaks off talks on CTBT.
1985—Start of unilateral Soviet moratorium on testing.
—U.S. seeks Soviet cooperation in exploration of ways to verify compliance with 150-kiloton limit of TTBT.
1987—Soviet Union renews testing.
—U.S.-Soviet talks on testing issues reopened.
1988—Exchange of visits by U.S. and Soviet weapons experts to testing sites to plan joint verification experiment.

Miller's report is a broader review of the various reasons for continued testing, especially the need to maintain an expert and experienced work force in the nuclear weapons community. He also states that the reliability of current weapons is very high and that most problems can be handled with nonnuclear testing. But he points out that nuclear weapons are subject to aging and that no weapons can be tested enough prior to deployment to guarantee no further nuclear testing will be needed.

The scientific community questioned the need for continued testing through more than 200 letters to David P. Gardner, president of the University of California, which manages the weapons labs for DOE. The letters were from University of California faculty members. They asked if today's nuclear weapons do, indeed, require continued testing and if the laboratory's weapons design policies were impeding the stated national goal of a comprehensive test ban.

The issue was referred for study to the Scientific & Academic Advisory Committee (SAAC), which provides Gardner with technical oversight of the labs. The subsequent report by SAAC does not directly address the issue of whether continued testing is needed to assure reliability in today's arsenal. But it states that the labs have "designed weapons that have been remarkably reliable and long-lived."

The report points out that weapons are prepared in accordance with so-called military characteristics provided by the Department of Defense in order of priority. In 1977 a "desirable" characteristic was introduced to address stockpile reliability and remanufacture. But it has not been assigned a priority. SAAC concludes that weapons have not been deliberately designed to require continued testing. On the contrary, according to SAAC, "In the past decade, increased emphasis on warhead endurance appears to be resulting in weapons that have even fewer problems in the stockpile."

The outlook for a ban

During the past two years the House has twice voted in favor of limiting nuclear testing to 1 kiloton or less if the Soviets do the same. The Senate has not gone along, being content with a nonbinding resolution encouraging the reopening of talks with the Soviets. But the pressure for progress on nuclear testing remains strong, if somewhat diluted, with the signing of the treaty on intermediate-range nuclear forces and the prospects of an agreement on reducing strategic forces later this year.

A lot will be decided concerning the future of test ban negotiations in November with the Presidential elections. If one of the Republican aspirants is successful, there likely will be little change from the current posture.

But if any of the Democratic aspirants becomes President there will be a strong call for change. All seven Democrats still in the race favor a test ban. Most give it high priority. Most state that they would call for a mutual testing moratorium with the Soviets as an early step. Of course, the opposition from the defense and weapons establishment will remain strong.

On the international scene there is growing, if still not compelling, pressure for the U.S. and the Soviet Union to finally live up to their 25-year-old commitment to negotiate a comprehensive ban. For instance, late last year the general assembly of the United Nations voted 128 for, three against, with 22 abstentions in favor of a proposal that the nonnuclear-weapons states submit an amendment proposal to change the LTBT into a comprehensive testing ban. The no votes were from the U.S., the U.K., and France.

This proposal very likely won't go anywhere. But the issue of nuclear weapons testing is not going to go away either, domestically or internationally. □

Drug testing: how it's being handled at the Winter Olympics Page 23

A125-0-1
2/26/88

FEBRUARY 22, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR6608SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Chemical Earnings Soar

Further big gains
in fourth-quarter 1987
Page 10

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 8
CENEAR 66 (8) 1–48
ISSN 0009-2347

FEBRUARY 22, 1988

News of the Week

- **Some federal R&D agencies, most notably NSF, fare quite well in President Reagan's proposed federal budget for fiscal 1989. Page 4**
- **House subcommittee concludes that White House Office of Science & Technology is operating satisfactorily, considering the political problems it faces. Page 5**
- **Several top-level Soviet scientists attending U.S. meeting describe Soviet research in their fields, outline sweeping reforms now under way as part of perestroika. Page 5**
- **New optical data storage medium, called "digital paper" by developer ICI Electronics, can store vastly more data than current disks and tapes, may revolutionize the computer industry as well as audio and video applications. Page 6**
- **Researchers successfully test system that allows genetic engineers to monitor altered organisms in the environment to follow their distribution and evaluate their performance. Page 6**

Cover: Degussa's hydrogen peroxide plant in Theodore, Ala.

Letters 2

Concentrates

Business 7
Government 15
Science/Technology 18

The Departments

Meetings 47
Newscripts 48

Government

EPA's final rule on toxic chemical release reporting requires annual reports on environmental releases of 308 specific chemicals and 20 categories of chemicals. **Page 16**

Clause in recently passed spending bill mandates that carbon fiber producers secure at least 50% of their polyacrylonitrile raw materials from U.S. sources by 1992. **Page 17**

Science

Two new classes of macromolecules are synthesized using branching strategies that allow construction of a large molecule with precisely controlled size, shape, and molecular weight. **Page 19**

Technology

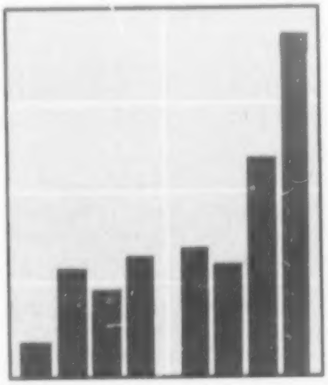
Drug testing at Winter Olympic Games in Calgary targets stimulants, narcotics and analgesics, anabolic steroids, beta blockers, and diuretics. **Page 23**

Books

"Coal: the Energy Source of the Past and Future," by Harold H. Schobert, considers the feasibility of coal as compared with other alternative energy sources. **Page 26**

ACS News

ACS urges changes to House chemical diversion bill, which is aimed at stopping the diverting of chemicals from their legitimate purposes to the making of illegal drugs. **Page 28**



Business

Capping a strong year, major chemical companies' earnings shot up 93% on a sales increase of 20% in fourth-quarter 1987; profitability reached 6.7%, up from 4.2% in fourth-quarter 1986. Page 10

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 47)

LETTERS

Patenting vaccines

SIR: I was surprised to read in your article on animal health products the assertion attributed to William H. D. Leaning that "vaccines themselves cannot be patented" (C&EN, Oct. 5, 1987, page 51). This would come as a surprise to patent attorneys, who have been patenting vaccines for some time. For example, U.S. Patent No. 3,470,294 has claims directed to a composite vaccine against canine distemper and hepatitis.

I recently received a notice of the allowance of an application on a vaccine against an insect-borne disease for a scientist at the University of Minnesota.

Warren D. Woessner
Patent Attorney, Minneapolis

Editor's note: C&EN should have made clear that William H. D. Leaning was referring to a specific case in which Merck was unable to patent a vaccine it developed in cooperation with the U.S. Department of Agriculture.

Cancer prevention

SIR: In the provocative article, "Rethinking the War on Cancer" (*Issues in Science and Technology*, Fall 1987, page 16), John C. Bailar III warns that we are losing the war against cancer. As he points out, our failure to lower the U.S. cancer death rate, despite an effort spanning 35 years, shows the need for a change in strategy.

To comprehend this revelation it is useful to probe the trends in U.S. cancer death rates. Information on this subject was also supplied by Bailar in a previous publication entitled "Progress Against Cancer" [*N. Engl. J. Med.*, **314,** 1226 (1986)]. There he reports that the cancer mortality rates, age-adjusted to the U.S. population of 1980—excluding lung cancer, cancer of the stomach, and cancer of the cervix—shifted from 130.1 in 1950 to 128.9 in 1980, a change of less than 1% in three decades.

It is this situation that prompted Bailar to declare, "It is difficult to claim success in the war against cancer on the basis of these figures." It was also this situation that prompted J. Cairns, a decade ago, to state in "Cancer: Science and Society": "For example, in the U.S., there has been little change in the incidence and death rate from cancer as a whole in the last 30 years during which time the annual production of pesticides, synthetic rubber, and plastics has risen more than 100-fold. Thus, it does not seem that industry can be made the scapegoat for the cancers that are common at the moment."

Now, since cancer death rates have not increased after the production of hazardous industrial chemicals rose 100-fold, and since cancer death rates have not decreased after the implementation of procedures to diminish exposure to hazardous industrial chemicals, there cannot be any conclusion other than that industrial chemicals are an insignificant factor in the causation of cancer.

It is instructive, in this connection, to compare the U.S. age-adjusted cancer mortality rates—which rose from 162.2 per 100,000 population in 1975 to 170.7 in 1984—with those of an essentially agricultural country with little chemical industry, such as New Zealand. Using equivalent figures—limited, however, to the male population—the New Zealand rates rose from 168 in 1973 to 174 in 1983. There is, certainly, no noticeable effect brought about by the U.S. chemical industry.

In conclusion, changes in strategy in the war against cancer are imperative. Research emphasis must be shifted from hazardous chemical carcinogens to the dietary and lifestyle changes needed to strengthen our immune system.

Ernest W. Volkmann
ACS Emeritus Member
Ligonier, Pa.

Periodic table long form

SIR: As William B. Jensen (C&EN, Aug. 17, 1987, page 2) stated, any labeling or shaping of the periodic table should perform a useful function, such as to locate elements or impart some pertinent information. The original numbering systems were devised by various authors in an attempt to defend the empirical structure of their tables.

Mendeleev justified his form of the table, particularly the gaps he left and the reversal of some of the elements as listed by atomic mass, by reference to the formula of the highest oxide of the elements and labeled the group in which he placed each element with the number of moles of oxygen that combined with 2 moles of that element in its highest oxide.

Correction

- Jan. 11, page 24: In the review of the book, "A Killing Wind: Inside Union Carbide and the Bhopal Catastrophe," the reviewer stated that the book's author, Dan Kurzman, was in error in attributing water as heavier than methyl isocyanate (MIC). Kurzman is in fact correct.

FEDERAL R&D BUDGET: Science gains despite deficit flap

Last week President Reagan sent his eighth and, for all practical purposes, his final budget proposal to Congress. Some of the government's R&D agencies, most notably the National Science Foundation, fare much better than average in a budget that is essentially no larger than the current year's budget, taking inflation into account.

The budget proposal calls for total government spending of $1.094 trillion in fiscal 1989, an increase of 4% over current levels, and a deficit of $129.5 billion. It is a no-growth budget, if the Administration's economists are right and the inflation rate hovers around 3.5% in 1989. Experiencing big growth, however, is science, underscored by a 20% rise in NSF's budget.

"In formulating this budget," Reagan told Congress, "I have endeavored to meet national priorities while keeping to the terms of the bipartisan budget agreement" worked out between Congress and the Administration last November. That agreement essentially limits increases in discretionary domestic spending to 2% and in defense spending to 3%. Among the "urgent national priorities" receiving larger than allowed increases is R&D.

NSF is big winner in 1989 R&D budget that is up 4% overall

$ Millions	1989^a	1988^a	1987^b	% change 1988-89
Defense	$38,787	$37,899	$36,088	2%
HHS	7,938	7,174	6,643	11
NASA	5,416	4,779	3,787	13
Energy	5,165	5,071	4,724	2
NSF	1,827	1,524	1,464	20
Agriculture	985	1,018	948	−3
Interior	396	419	403	−5
EPA	374	350	348	7
Transportation	317	325	322	−2
Commerce	312	408	405	−24
All other	1,000	984	960	2
TOTAL	$62,517	$59,951	$56,090	4%

Note: Obligations. a Estimate. b Actual. Source: Office of Management & Budget

Total federal obligations for R&D are slated to rise 4% to $62.5 billion. And, in line with the budget agreement, funding for civilian R&D, up 8% to $23.7 billion, would grow at a faster rate than defense R&D, up 2% to $38.8 billion, for the first time in many years.

Obligations for basic research would rise 6% to $10.3 billion. Within that total, federal support for academic R&D is estimated to increase 13% in 1989 to a total of $9.2 billion. This, budget documents note, would represent a real increase of 54% over the term of the Reagan Administration.

A number of science and technology issues are among Reagan's top priorities as delineated in the budget message. For example:

- "I would provide $11.5 billion for space programs, including essential funding for continued development of America's first permanently manned space station.
- "I also recommend $363 million in 1989 to initiate construction of the Superconducting Super Collider, including $283 million for construction and $60 million for supporting research and development. The SSC as currently envisaged will be the largest pure science project ever undertaken.
- "To attack the scourge of AIDS [acquired immune deficiency syndrome], I propose $2 billion for research, treatment, and education in 1989—a 38% increase over the 1988 level and more than double the federal government's efforts in 1987."

And the Administration is holding to the commitment it made last year to double funding for NSF within five years, However, because of severe fiscal 1988 budget cuts, the target date is now 1994, rather than the original 1993. As a first installment, it is asking for a 20%, $303 million increase to $1.8 billion for NSF in fiscal 1989. If things go as the Administration wishes in other areas, the National Aeronautics & Space Administration's R&D budget will be up 13%, or $637 million, to $5.4 billion, and the Department of Health & Human Services' R&D budget will be up 11%, or $764 million, to $7.9 billion.

Not all is rosy for science, however. Funding for the National Institutes of Health would decline slightly, just over 1%, to $6.2 billion. R&D funding for the Department of Energy's energy programs also would be down about 1% to $2 billion, for the Department of Interior down 5% to $396 million, and for the Department of Agriculture down 3% to $985 million.

Taking the biggest hit are the Department of Commerce's research programs, funding for which would be down 24%, or $96 million, to $312 million. The Administration once again wants to eliminate the National Oceanic & Atmospheric Administration's underseas research and sea grant college programs.

Congress hasn't gone along with those ideas in the past and isn't likely to do so this year either. However, insofar as this budget does adhere to the November budget agreement, it may be difficult for Congress to make wholesale changes in priorities and spending levels as it has in other years, even though, as Reagan put it, "This budget does not fully reflect my priorities, nor, presumably, those of any particular member of Congress."

Janice Long, Washington

Chemical Earnings Score Huge Gains in Fourth Quarter

William J. Storck, C&EN New York

It was not so long ago that many observers thought the U.S. chemical industry was all but dead. Huge in volume and highly cyclical, petrochemicals especially came in for their share of blame. Production of these products, many said, would migrate to areas of the world where feedstock costs were low, leaving the U.S. with just a modest petrochemical industry.

How times do change—and quickly. Spurred by U.S. and foreign demand, U.S. petrochemical producers helped push the chemical industry to new levels of profits in last year's fourth quarter, to the point that now there are finally plans to build some new U.S. capacity.

Performance by the chemical industry in the fourth quarter was nothing short of outstanding. Chemical executives had said that the quarter was going to be good for their firms, but probably few realized just how good overall it was actually going to turn out. Among a representative group of the largest chemical companies, sales increased 20% from year-earlier levels and earnings soared a phenomenal 93%.

This outdid by far any of the other industry categories charted by C&EN. Among oil companies that produce chemicals, earnings rose 47% (from fourth-quarter 1986) on a 21% sales increase. Pharmaceutical firms' earnings climbed 13% on an 11% increase in sales. And among diversified companies with chemical operations, earnings rose 48% and sales improved 17%.

Chemical industry leaders cite

Chemical industry leaders for the fourth quarter . . .

Sales

Rank 1987		$ Millions	Rank 1986
1	Dow Chemical	$3579.0	1
2	Monsanto	1846.0	3
3	Union Carbide	1845.0	2
4	W. R. Grace	1304.8	4
5	American Cyanamid	1025.0	5
6	Quantum Chemical	742.3	7
7	Hercules	678.0	6
8	Air Products	585.9	8
9	Rohm & Haas	531.9	10
10	Arco Chemical	507.0	nr

Earnings

	$ Millions	Rank 1986
Dow Chemical	$354.0	1
Arco Chemical	72.0	nr
Quantum Chemical	65.1	7
American Cyanamid	60.2	2
Air Products	55.4	6
W. R. Grace	53.3	30
Ethyl	52.9	4
Hercules	48.8	3
Monsanto	44.0	9
Rohm & Haas	36.7	5

Profitability

	Earnings as % of sales	Rank 1986
Georgia Gulf	17.4%	nr
Vista Chemical	14.2	nr
Arco Chemical	14.2	nr
International Flavors	11.9	2
Ethyl	11.2	1
Betz Laboratories	10.1	4
Dow Chemical	9.9	14
Nalco Chemical	9.6	3
Air Products	9.4	10
Loctite	9.3	6

. . . and for full-year 1987

Sales

Rank 1987		$ Millions	Rank 1986
1	Dow Chemical	$13,377.0	1
2	Monsanto	7,639.0	2
3	Union Carbide	6,914.0	3
4	W. R. Grace	4,515.4	5
5	American Cyanamid	4,166.1	4
6	Hercules	2,693.0	6
7	Quantum Chemical	2,566.8	11
8	Rohm & Haas	2,203.2	8
9	Air Products	2,184.3	9
10	Arco Chemical	1,952.0	nr

Earnings

	$ Millions	Rank 1986
Dow Chemical	$1245.0	1
Monsanto	436.0	2
Arco Chemical	267.0	nr
American Cyanamid	264.0	4
Union Carbide	232.0	9
Hercules	209.3	3
Rohm & Haas	195.5	6
Ethyl	193.3	5
Air Products	176.5	8
Quantum Chemical	143.6	16

Profitability

	Earnings as % of sales	Rank 1986
International Flavors	14.3%	1
Arco Chemical	13.7	nr
Georgia Gulf	13.0	nr
Ethyl	11.2	2
Betz Laboratories	10.5	3
Vista Chemical	10.0	nr
Loctite	9.7	6
Nalco Chemical	9.5	7
Dow Chemical	9.3	13
Rohm & Haas	8.9	8

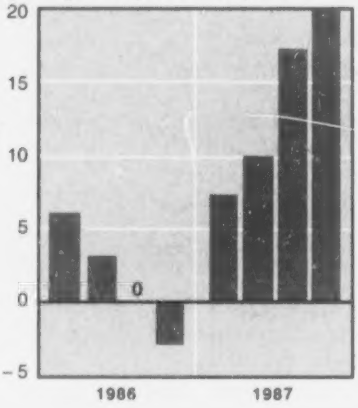
Note: Based on 30 companies listed on page 12. **nr** = not ranked.

Chemical industry 1987 fourth-quarter results

- Sales increased 20%
- Earnings skyrocketed
- Profit margins stayed high
- Production climbed 7.2%
- Prices rose nearly 7%

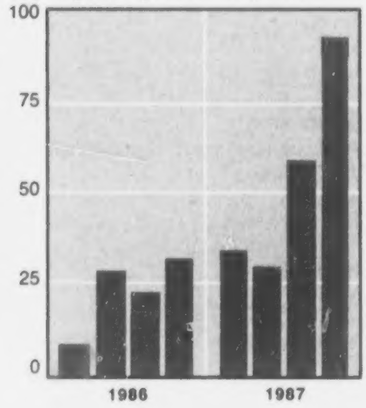
Sales

% change from year-earlier quarter



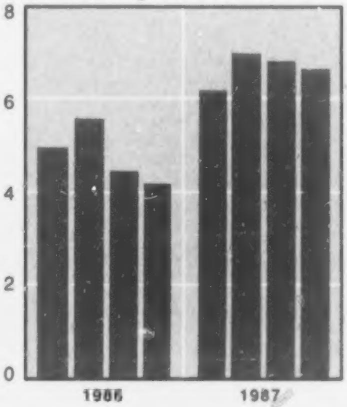
Earnings

% change from year-earlier quarter



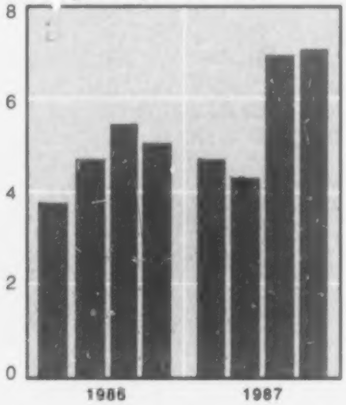
Profit margins

After-tax earnings as % of sales



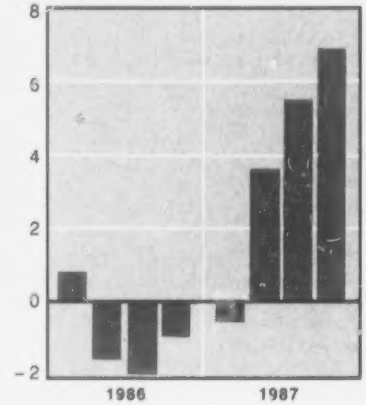
Production

% change from year-earlier quarter



Prices

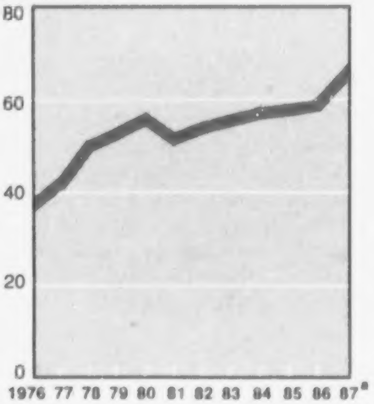
% change from year-earlier quarter



Sales in 1987 rose 14% and earnings shot up 50%, pushing profit margins up to 6.7%

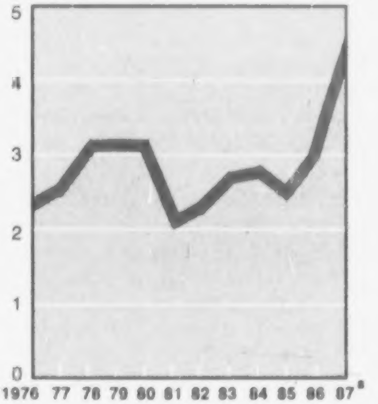
Annual sales

$ Billions



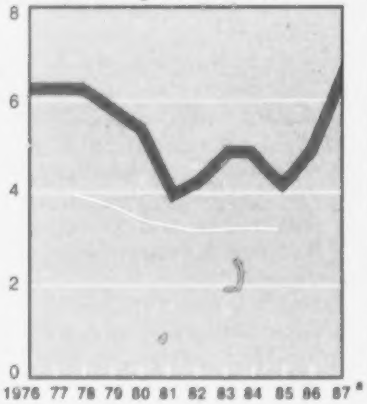
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit margin data are based on combined results of 30 companies listed on page 12. a C&EN estimates

Earnings nearly doubled at major U.S. chemical firms in fourth quarter

	FOURTH-QUARTER 1987						FULL-YEAR 1987				NINE-MONTHS 1987	
	Sales	Earnings[a]	Change from 1986		Profit margin[b]		Sales	Earnings[a]	Change from 1986		Profit margin[b]	
	($ millions)		Sales	Earnings[a]	1987	1986	($ millions)		Sales	Earnings[a]	1987	1986
Air Products[c]	$ 585.9	$ 55.4	10%	56%	9.4%	6.6%	$ 2,184.3	$ 176.5	7%	27%	8.1%	6.8%
American Cyanamid[c]	1,025.3	60.2	8	16	5.9	5.5	4,166.1	264.0	9	30	6.3	5.3
Arco Chemical[c]	507.0	72.0	27	148	14.2	7.3	1,952.0	267.0	27	87	13.7	9.3
Aristech	241.9	21.4	37	88	8.8	6.5	918.8	69.7	22	59	7.6	5.8
B. F. Goodrich[c]	na	na	na	na	na	2.6	na	na	na	na	na	0.5
Betz Laboratories	99.7	10.0	17	40	10.1	8.4	385.9	40.6	12	14	10.5	10.3
Cabot[c]	386.7	16.2	12	−14	4.2	5.4	1,381.3	56.1	6	−9	4.1	4.7
Chemed	99.7	4.7	7	26	4.7	4.1	391.0	20.4	9	23	5.2	4.6
Crompton & Knowles	58.3	3.1	8	43	5.3	4.0	237.5	11.8	11	32	4.9	4.2
Dow Chemical[c]	3,579.0	354.0	28	109	9.9	6.1	13,377.0	1245.0	20	68	9.3	6.7
Ethyl[c]	470.6	52.9	21	16	11.2	11.7	1,720.3	193.3	9	9	11.2	11.3
First Mississippi	85.8	3.1	38	269	3.6	1.3	326.2	20.9	32	330	6.4	2.0
Georgia Gulf	201.9	35.1	39	205	17.4	7.9	707.4	91.7	21	134	13.0	6.7
H. B. Fuller	153.2	7.3	10	41	4.8	3.7	597.1	25.8	13	36	4.3	3.6
Hercules[c]	678.0	48.8	6	3	7.2	7.4	2,693.0	209.3	3	−8	7.8	8.7
International Flavors	179.3	21.3	23	26	11.9	11.6	745.9	107.0	20	25	14.3	13.8
International Minerals[c]	460.4	34.5	21	def	7.5	def	1,801.6	75.2	15	def	4.2	def
Loctite	103.2	9.6	27	51	9.3	7.8	383.4	37.1	31	46	9.7	8.7
Lubrizol	na	na	na	na	na	6.3	na	na	na	na	na	8.0
Monsanto[c]	1,846.0	44.0	18	91	2.4	1.5	7,639.0	436.0	11	19	5.7	5.3
Nalco Chemical	230.7	22.0	22	37	9.6	8.5	841.9	80.3	14	26	9.5	8.7
Olin[c]	503.0	16.0	21	100	3.2	1.9	1,930.0	78.0	11	34	4.0	3.3
Pennwalt	300.5	17.0	14	45	5.7	4.4	1,142.8	53.8	9	6	4.7	4.8
Petrolite	78.0	3.7	18	4	4.7	5.4	278.6	15.4	0	−12	5.5	6.2
Quantum Chemical[c]	742.3	65.1	37	121	8.8	5.4	2,566.8	143.6	48	161	5.6	3.2
Rohm & Haas[c]	531.9	36.7	14	2	6.9	7.6	2,203.2	195.5	7	15	8.9	8.2
Union Carbide[c]	1,845.0	23.0	16	64	1.2	0.9	6,914.0	232.0	9	78	3.4	2.0
Vista Chemical	178.8	25.5	37	196	14.2	6.6	657.5	65.5	17	71	10.0	6.8
W. R. Grace[c]	1,304.8	53.3	23	def	4.1	def	4,515.4	142.0	21	def	3.1	def
Witco	368.4	17.8	13	8	4.8	5.1	1,427.7	68.1	5	4	4.8	4.8
Total 14 larger firms	**$14,465.9**	**$ 932.1**	**20%**	**100%**	**6.4%**	**3.9%**	**$55,044.0**	**$3713.5**	**15%**	**53%**	**6.7%**	**5.0%**
Smaller 14 firms	**$ 2,379.4**	**$ 201.6**	**22%**	**66%**	**8.5%**	**6.2%**	**$ 9,041.5**	**$ 708.0**	**14%**	**38%**	**7.8%**	**6.5%**
GRAND TOTAL	**$16,845.3**	**$1133.7**	**20%**	**93%**	**6.7%**	**4.2%**	**$64,085.5**	**$4421.5**	**14%**	**50%**	**6.9%**	**5.3%**

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c One of the 15 largest companies. na = not available. **def** = deficit

many reasons for the vastly improved performance. Some say that they have further reduced operating costs during the past year. Others credit a further shucking of marginally profitable businesses. Still others point to new product lines. But, in the final analysis, most agree that the primary reason was that business was good.

During the quarter, U.S. chemical production was up an estimated 7% over the previous year's final three months, and prices increased almost as much, according to government data. Price increases were, of course, largely driven by production. Capacity utilization in the industry was very high—more than 100% for some products. This high capacity use increased operating efficiencies and the tight supply-demand situation paved the way to price rises, thus hiking profitability.

For instance, Georgia Gulf's chairman, president, and chief executive officer James R. Kuse says: "Sales demand actually improved during the fourth quarter, allowing our plants to operate at or near capacity, helping to reduce unit costs. This, coupled with higher sales prices, resulted in substantially improved margins for most products."

Aristech chairman and chief executive officer Thomas Marshall says, "Aristech's first year was characterized by a number of highly positive factors for our business. Demand for our major products remained strong throughout the year. The supply-demand balance was such that many of our plants and much of the industry operated at or near capacity for essentially the entire year. This was especially true in polypropylene and industrial chemicals."

The upshot was vastly improved results. Among 28 of the 30 largest chemical companies regularly sur-

Earnings improved dramatically at oil, pharmaceutical, and diversified companies

	FOURTH-QUARTER 1987						FULL-YEAR 1987					
	Sales	Earnings[a]	Change from 1986		Profit margin[b]		Sales	Earnings[a]	Change from 1986		Profit margin[b]	
	($ millions)		Sales	Earnings	1987	1986	($ millions)		Sales	Earnings	1987	1986
OIL AND GAS COMPANIES												
American Petrofina	$ 671.6	$ 13.6	34%	170%	2.0%	1.0%	$ 2,484.0	$ 83.3	27%	def	3.4%	def
Amoco	5,916.0	377.0	22	128	6.4	3.4	22,391.0	1360.0	11	50%	6.1	4.5%
Ashland	2,000.0	40.0	25	48	2.0	1.7	7,613.0	130.0	11	9	1.7	1.7
Chevron	7,300.0	220.0	26	−4	3.0	4.0	29,100.0	1007.0	7	41	3.5	2.6
Exxon	22,586.0	1556.0	18	5	6.9	7.7	84,116.0	4841.0	10	−10	5.8	7.0
Kerr-McGee	640.7	14.7	9	67	2.3	1.5	2,607.6	84.0	3	245	3.2	1.0
Mobil	15,662.0	529.0	25	161	3.4	1.6	56,446.0	1404.0	13	0	2.5	2.8
Occidental Petroleum	4,389.0	23.0	5	15	0.5	0.5	17,096.0	184.0	11	7	1.1	1.1
Phillips Petroleum	2,932.0	−10.0	23	def	def	0.2	10,917.0	−8.0	9	def	def	5.8
Shell Oil	5,888.0	436.0	30	1717	7.4	0.5	21,222.0	1230.0	22	39	5.8	5.1
Sun Co.	2,610.0	83.0	16	19	3.2	3.1	9,820.0	348.0	−7	−10	3.5	3.6
Texaco	9,400.0	138.0	21	176	1.5	0.6	35,300.0	493.0	8	−32	1.4	2.2
PHARMACEUTICAL COMPANIES												
Abbott Labs	281.4	22.5	4	214	8.0	2.7	928.8	54.3	10	1551	5.9	0.4
American Home Products	1,213.4	215.2	2	8	17.7	16.7	5,028.3	845.1	2	9	16.8	15.8
Baxter Travenol	1,647.0	90.0	11	43	5.5	4.3	6,223.0	323.0	9	68	5.2	3.4
Becton Dickinson	397.4	24.5	16	33	6.2	5.3	1,635.8	139.1	18	21	8.5	8.3
Bristol-Myers	1,360.6	174.1	13	15	12.8	12.6	5,401.2	709.6	12	20	13.1	12.2
Eli Lilly	904.9	191.6	6	1	21.2	22.1	3,643.8	931.9	10	10	25.6	25.4
Merck	1,394.4	232.4	21	35	16.7	15.0	5,061.3	906.4	23	34	17.9	16.4
Pfizer	1,275.2	136.6	10	−14	10.7	13.6	4,919.8	690.2	10	5	14.0	14.7
Schering-Plough	663.3	75.2	11	26	11.3	10.0	2,699.3	316.4	13	19	11.7	11.1
SmithKline Beckman	1,198.7	141.9	15	−4	11.8	14.1	4,328.8	570.1	16	9	13.2	13.9
Squibb	592.6	84.6	15	26	14.3	13.1	2,156.5	358.4	21	36	16.6	14.8
Sterling Drug	592.4	51.8	13	15	8.7	8.6	2,300.9	330.0	16	10	14.3	15.1
Upjohn	649.7	71.0	11	10	10.9	10.9	2,521.0	305.0	11	21	12.1	11.1
Warner Lambert	909.7	66.3	12	17	7.3	7.0	3,484.7	295.8	12	−4	8.5	10.0
DIVERSIFIED MANUFACTURERS												
Allied-Signal	2,954.0	77.0	17	64	2.6	1.9	11,116.0	515.0	12	−4	4.6	5.5
Borden	1,804.2	81.3	33	18	4.5	5.1	6,514.4	267.1	30	20	4.1	4.5
Du Pont	7,941.0	439.0	19	31	5.5	5.0	30,468.0	1786.0	12	17	5.9	5.6
Eastman Kodak	3,529.0	242.0	17	227	6.9	2.4	13,305.0	1178.0	15	15	8.9	8.9
Engelhard	728.1	15.7	4	10	2.2	2.0	2,479.2	72.8	8	37	2.9	2.3
Ferro	232.9	11.2	24	37	4.8	4.3	871.1	33.5	20	35	3.8	3.4
FMC	856.3	5.5	10	−89	0.6	6.5	3,139.1	96.2	5	−25	3.1	4.3
GAF	209.1	19.5	15	2	9.3	10.5	836.9	100.1	11	24	12.0	10.7
Kaiser Tech[c]	456.4	28.0	−6	def	6.1	def	1,987.2	13.4	1	def	0.7	def
Koppers	420.4	16.1	14	5	3.8	4.2	1,515.7	70.2	9	11	4.6	4.5
3M	2,375.0	216.0	12	17	9.1	8.8	9,429.0	918.0	10	18	9.7	9.1
Morton Thiokol	584.8	39.3	27	21	6.7	7.0	1,008.7	79.9	11	22	7.9	7.2
PPG Industries	1,330.0	96.5	11	32	7.3	6.1	5,180.0	377.1	10	19	7.3	6.7
Tyler	283.2	5.0	20	3622	1.8	0.1	1,099.5	16.8	14	41	1.5	1.2
Vulcan Materials	246.3	28.5	25	85	11.6	7.8	923.3	114.5	15	25	12.4	11.4

a After-tax earnings from operations excluding significant nonrecurring and extraordinary items. **b** After-tax earnings as a percentage of sales. **c** Includes some nonrecurring or extraordinary items. **def** = deficit.

veyed by C&EN, chemical sales gained 20% from fourth-quarter 1986 to a total of $16.8 billion. Earnings from continuing operations, excluding major nonrecurring and extraordinary items, rose 93% to a total $1.13 billion. The average profit margin (after-tax earnings as a percentage of sales) for this group of companies reached 6.7%, up from just 4.2% in the fourth quarter of 1986.

The increase in earnings at the larger companies, more heavily dominated by basic chemicals, was even more impressive. Among the 14 larger companies in the group, combined earnings totaled $932 million, double the total a year earlier. Combined sales increased 20% to $14.5 billion. Profit margins among these firms averaged 6.4%, an increase from 3.9% a year earlier.

For the 14 smaller firms in the group, which are more oriented toward value-added chemicals, earnings increased much less, but profitability continued higher. These companies' combined earnings increased 66% to a total $202 million on a sales jump of 22% to $2.38 billion. The average profit margin for these firms increased to 8.5% from 6.2% in fourth-quarter 1986.

For the full year, the story was much the same. Combined earnings for the 28 chemical companies rose 50% from full-year 1986 to a total of $4.42 billion. Combined sales rose 14% to $64.1 billion. Thus profit margins rose to an average 6.9% from 5.3% for all of 1986.

For the 14 larger companies, earnings increased 53% to a combined $3.71 billion on a sales rise of 15% to $55.0 billion. For the 14 smaller firms, combined earnings gained 38% to $708 million on a 14% sales increase to $9.04 billion.

But again, the smaller companies bested the larger firms in profitability. Profit margins for the 14 smaller firms increased to an average 7.8% from 6.5% a year earlier; profit margins for the 14 larger firms climbed to 6.7% from 5.0%.

Company officials commenting on the earnings performance are almost unanimous in their praise of the fourth quarter and the year. Rohm & Haas chairman Vincent L. Gregory Jr. says: "1987 ended in high gear. Business was strong in nearly every product line and across all geographic regions. The year-to-year sales growth for the fourth quarter was the best of any quarter in 1987. External economic conditions in the chemical industry were favorable around the world, and the increased acceptance of our products was gratifying. Most of the nonagricultural businesses operated at high levels. Their volume growth enabled us to achieve improved profit performance for the quarter and establish a record for the full year."

For Arco Chemical, recently spun off from Atlantic Richfield, president and chief executive officer Harold A. Sorgenti comments that "The overall improvement in gross profit is attributable to increased sales volumes and increased margins. Sales volumes of propylene oxide and derivatives and oxygenated fuels increased 18% each. Worldwide propylene oxide demand increased approximately 7% in 1987 over 1986."

Olin president and chief executive officer John W. Johnstone Jr. says: "Operating income doubled in the quarter and was up 40% for the full year as chemicals produced their best operating results in over a decade."

Ethyl's chairman Floyd D. Gottwald Jr. notes that, "Aided by improved fourth-quarter results in almost every segment, 1987 was a banner year for Ethyl. Plastics continued to lag behind 1986. We are particularly encouraged by the performance of our chemicals operations, with bromine chemicals showing notable strength."

Frank P. Popoff, president and chief executive officer at Dow Chemical, says: "Basic chemicals and plastics continued their outstanding performance in the fourth quarter and for the year. In 1987, polystyrene became the first Dow product to surpass $1 billion in sales. Polyethylene also had a significant volume increase, giving rise to the expectation that 1988 business will continue to be strong for both these plastics."

Just what 1988 will bring for the chemical industry is of great concern to industry leaders. Most seem to be optimistic. For instance:

- Olin's Johnstone: "Sales and earnings momentum for the fourth quarter is continuing into the first quarter of 1988. Demand is strong for chemicals and metals, with important price increases in place."
- Aristech's Marshall: "Based on market expectations, anticipated plant utilization rates, and capacity improvements, we expect to maintain the momentum in growth, profitability, and financial strength with which we concluded 1987."
- Georgia Gulf's Kuse: "We have not seen any sign of a slowdown in the markets we serve, and based on existing orders and inventories, we have reason to be bullish about the company's performance for 1988."

However, given talk among economists and Wall Street analysts of a slowdown in the economy, there are varying degrees of caution in what the chemical executives say about 1988. A sampling:

- Air Products & Chemicals chairman Dexter F. Baker: "[Our] outlook for profit growth for the year is clearly positive, although tempered by the uncertain current outlook for world economies."
- Du Pont chairman and chief executive officer Richard E. Heckert: "We expect 1988 to be a challenging year given the uncertainty surrounding the domestic and world economies. However, we are confident that the company is well positioned to compete effectively in this environment."
- Hercules chairman and chief executive officer David S. Hollingsworth: "As 1988 begins, housing starts and consumer spending trends were weakening somewhat, while the manufacturing segment remained strong due to a positive momentum in export shipments. Although Hercules has had no indication of an overall business downturn, we approach 1988 with a certain degree of caution. Nonetheless, we are anticipating a year of improvement in 1988."
- Rohm & Haas' Gregory: "Conditions in the chemical industry are the best that they have been in years. As long as the economy holds together, we should continue to show earnings gains. When the inevitable downturn comes, we, along with all industrial companies, will face tough sledding." □

A1250-1
3/4/88

FEBRUARY 29, 1988
CHEMICAL & ENGINEERING
NEWS

Federal R&D Budget '89

Administration seeks increase
despite deficit problems
Page 7

0511179C098 9 K AR6609SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 66, Number 9
CENEAR 66 (9) 1–44
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

FEBRUARY 29, 1988

News of the Week

- **Presidential Commission on AIDS issues first national policy recommendations, urging speedup in drug development, health care, and IV drug abuse treatment and prevention.** **Page 4**
- **Court rules that Occidental Chemical Corp. must pay for Love Canal cleanup, estimated at about $250 million.** **Page 5**
- **New test for AIDS antibodies developed by SmithKline Beckman will reduce or eliminate false positive tests, the company says.** **Page 5**
- **NSF survey finds that high percentage of primary and secondary school science and math teachers are poorly trained and that many feel unqualified to teach these subjects.** **Page 6**
- **Despite continuing Congressional opposition, the Administration persists in its efforts to privatize the National Technical Information Service.** **Page 6**

Letters 2

Concentrates

Business 13
Government 17
Science/Technology 21

The Departments

People 43
Newscripts 44

Business

Canada's four major chemical firms ended 1987 on high note, with combined profits climbing 70%, sales 20% in fourth quarter. **Page 15**

U.S. market for sealants will grow steadily to reach 1.5 billion lb valued at $2.3 billion by 1991. **Page 16**

Government

Role of White House science office is focus of renewed debate within technological community, with leaders pressing for new perspectives, increased stature for office. **Page 18**

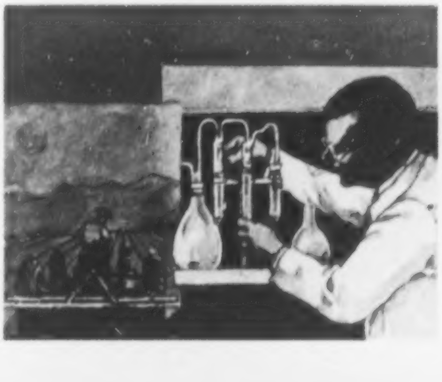
Science

Hadamard-transform techniques are attracting increased interest as promising alternatives to Fourier-transform methods for high-speed or high-sensitivity spectroscopy. **Page 22**

Seasonal Antarctic ozone depletion may result in dilution of ozone at other latitudes, say researchers in a presentation at the recent AAAS annual meeting. **Page 26**

Books

"Invisible Frontiers: The Race To Synthesize a Human Gene" by Stephen S. Hall provides insights on the establishment of the biotechnology industry. **Page 27**



News Focus

In President Reagan's fiscal 1989 budget proposal, funding for scientific research and development rises 4% to $62.5 billion, with defense, as usual, taking the largest share. **Page 7**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 43)

LETTERS

Frontier research cooperation

SIR: I read with great interest on the editorial page (C&EN, Jan. 4, page 5) excerpts of the speech by Rep. Sherwood L. Boehlert (R.-N.Y.) on the Superconducting Super Collider (SSC) before the assembled physicists.

Boehlert made a number of fundamental statements with extraordinary clarity. He said, "I support the SSC because I think human beings must continue to probe the nature of matter, to understand the forces that affect our lives. I believe that the U.S. has an obligation to push that quest forward. . . . An SSC cannot credibly be promoted as a device to promote economic competitiveness.

"The reasons for my discomfort with the SSC are easier to state. They can be boiled down to one word: money. . . . The best way to limit the cost of the SSC to the U.S. is to entice other nations to contribute. Yet [the Department of Energy] seems singularly unenthusiastic about this prospect. The reasons for this are unclear. Department officials repeat the phrase 'an American project within American borders' with mind-numbing frequency, as if it were some sort of mantra.

"The reality is that if the U.S. is going to engage in 'big science' it simply cannot afford to 'go it alone.' "

In a few short sentences, Boehlert succinctly summarized the economic reality of frontier research in all areas of science—space, molecular biology, astronomy, immunology, ecology, microelectronics, bioengineering, etc.—not just of high-energy physics. He also provided the most obvious as well as the logical solution: international cooperation. He correctly implied that full participation in frontier research is a responsibility of all civilized nations; we cannot shirk it. Human civilization is indivisible and its progress must be without interruption.

Both the capitalist and the socialist countries can fully participate in these endeavors and avoid economic waste, needless duplication, and the reinvention of the wheel. For example, the U.S.S.R. is decidedly better in rocketry and space-station hardware than we are, whereas we are well ahead of them in microelectronics and computing. Cooperation will benefit both nations. Such cooperation will also build confidence in each other.

The problem is that most frontier research has direct or indirect military implications, and therefore the military of every nation is always irreconcilably against such international cooperation. Boehlert should know that the Department of Energy is interlocked with military and that should explain DOE's strange mantra chanting. Historically, military's goal is dominance over others and not fraternity with others. Therefore, as long as the arms race continues, the doctrine of "position of strength" is adhered to, and ideological zealotry is propagated, genuine international cooperation is theoretically impossible, and mankind plunges toward economic ruination. Signs are quite visible.

Buddhadev Sen
Emeritus Professor of Chemistry
Louisiana State University

Support for risk communication

SIR: The National Science Foundation has asked us to clarify that our center, which is studying risk communication (C&EN, Oct. 26, 1987, page 22), is a Carnegie Mellon University Center. Much of the work we are doing in this center is supported by NSF, but NSF has not made a "center grant" to us in this area.

M. Granger Morgan
Head, Department of Engineering
and Public Policy
Carnegie Mellon University

Ozone layer rejuvenation

SIR: Leon Sadler (C&EN, Nov. 9, 1987, page 2) proposes to solve the ozone depletion problem by using airplanes or other techniques to carry ozone upward for stratospheric release. He calculates the total mass of pure ozone to be 3.3×10^{12} kg and then suggests that if there is a 6% depletion over 100 years, only 5.4×10^{6} kg per day would be needed to make up the deficit. Because this is only 2% of the U.S. airline freight load, Sadler suggests that ozone depletion has a ready technological solution. Were ozone like water sitting in a tank with a very small leak, Sadler's analysis would be correct. Ozone, however, and the atmosphere, are very dynamic. In the upper tropical stratosphere the lifetime of an individual ozone molecule is very short (seconds) and despite plausibly rapid ozone additions, the system would return to a perturbed equilibrium state determined by the amount of odd chlorine, nitrogen, and other species that catalytically control ozone abundance. In addition, it is at these altitudes where ozone depletion can be tens of percent, not just a few percent.

At lower stratospheric altitudes, the ozone created at higher altitudes is mov-

Funds for R&D Are Up 4% in Administration's Budget Proposal

NSF budget would rise 19%, putting the agency back on the track of doubling its funding over five years, whereas the rapid expansion in defense R&D would be halted, at least temporarily

Janice R. Long and David J. Hanson, C&EN Washington

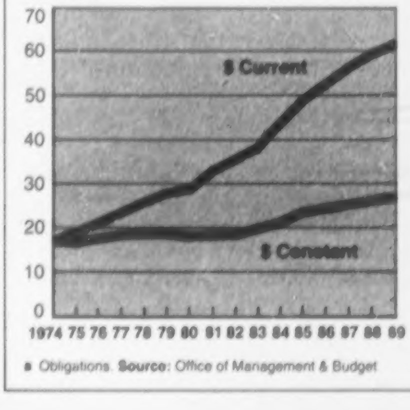
In the fiscal 1989 budget proposal that President Reagan sent to Congress on Feb. 18, funding for scientific research holds its own in a federal budget that rises 4% to $1.094 trillion (C&EN, Feb. 22, page 4). In the proposal, total R&D obligations are up 4% from fiscal 1988, or $2.6 billion, to $62.5 billion, with obligations for basic research up 6%, or $617 million, to $10.3 billion. Obligations for R&D facilities, which are not included in those amounts, are up 6% to $2.1 billion.

If Congress agrees to those numbers without making any changes—and that's unlikely—it means that federal R&D funding has increased some 240% over the past 15 years. Even adjusted for inflation that growth is impressive: In constant-dollar terms, R&D funding has increased more than 45% from $17.4 billion in 1974 to $25.5 billion in 1989.

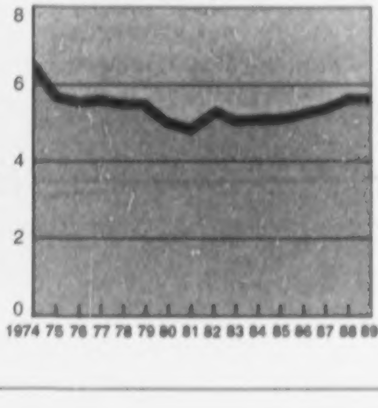
That growth is shared by almost all of the major federal research agencies. Based on the proposed 1989 figures, funding for defense R&D, including the Department of Energy's work, has grown 81% since 1974 to $17 billion in constant-dollar terms, 87% for the National Institutes of Health to $2.6 billion, 41% for energy R&D to $1.2 billion, and 30% for the National Science Foundation to $700 million. However, R&D funding for the National Aeronautics & Space Administration has dropped 35% in real terms to $2.1 billion.

Because the recently submitted budget is the final one on which Reagan will have a direct impact, it's now possible to trace R&D funding during his entire Administration—fiscal years 1982 through 1989. It's a fairly consistent pattern, given the Administration's emphasis on defense and basic research as opposed to applied research and development, which it feels is best done by the private sector. During the Reagan years, total R&D has increased 36% in terms of constant 1974 dollars. Funding for defense R&D has risen

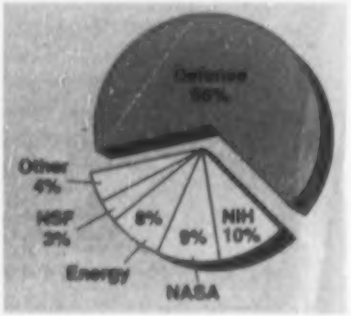
Proposed R&D budget shows little real growth . . .



. . . but R&D still takes nearly 6% of outlays . . .



. . . and defense accounts for largest share of total R&D



a Obligations. **Source:** Office of Management & Budget

Glossary of budget terms

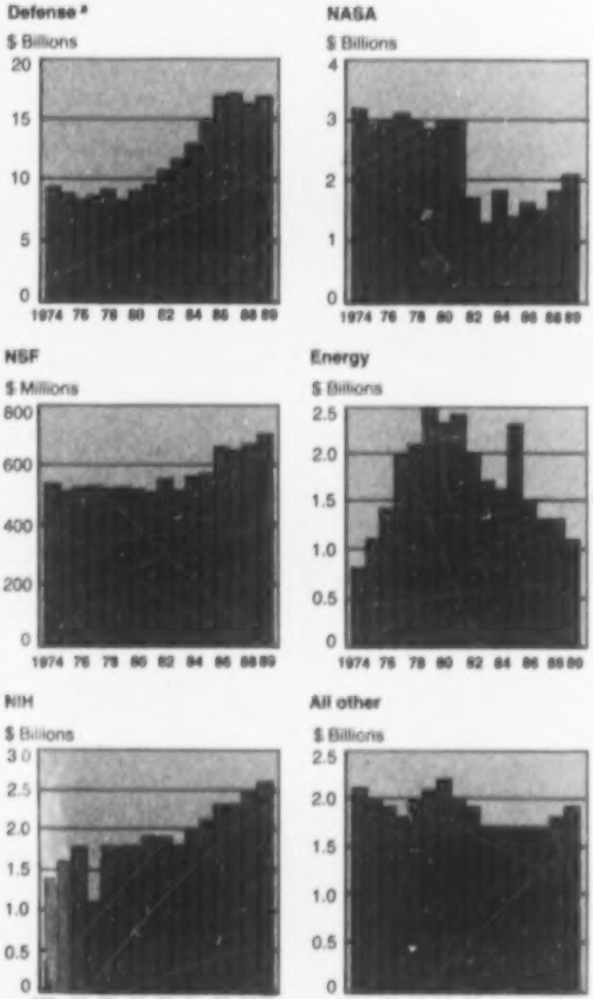
Fiscal year. Year running from Oct. 1 to Sept. 30. The fiscal year is designated by the calendar year in which it ends.

Obligations. Commitments made by federal agencies to pay out money for products, services, or other purposes, as distinct from the actual payment.

Outlays. Payments for obligations incurred under Congressionally granted budget authority generally made by issuance of checks on the Treasury. Outlays during any fiscal year may be for obligations incurred in prior fiscal years or in the same fiscal year.

Note. The R&D numbers obtained from individual agencies frequently differ from those used by the Office of Management & Budget in preparing its analysis of total federal R&D funding.

Since 1974, defense R&D has grown more than 80%, health research almost 90%



Note: Outlays in constant 1974 dollars. a Includes Department of Defense and Department of Energy programs. **Source:** Office of Management & Budget

59%, NIH 43%, NSF 27%, and NASA 19%. However, funding for energy R&D has declined 43%, primarily because of cutting large demonstration projects, and funding also has fallen for agricultural research, down 5% to $357 million, and for natural resources and environmental R&D, down 13% to $394 million.

With the 1989 budget proposal, the rapid expansion in defense R&D has been halted, at least temporarily. The Administration has requested the smallest increase in Department of Defense R&D in many years, reflecting the restraints set by the bipartisan budget agreement worked out between Congress and the Administration in November of last year. That agreement called for a 2% cap on increases in discretionary domestic spending and a 2.6% cap on military spending. DOD's R&D budget isn't rising by even that much. With only a 2% rise from fiscal 1988 in overall obligations, to $38.0 billion, most programs are maintained at their current levels. Still, DOD's spending equals about 60% of all federal R&D funding proposed for fiscal 1989.

In the new budget, the research end of DOD's research, development, test, and evaluation programs—called technology base and advanced technology development—gets a slight increase to $3.3 billion, from $3.1 billion in 1988. The Administration says two of the areas receiving increased emphasis this year are materials research and electronics. Two other areas getting high priority are "very high speed integrated circuits" and "millimeter wave monolithic integrated circuits."

In the advanced technology area, most of the 15% increase, $855 million, is going to the President's controversial program for protection against nuclear missiles, the Strategic Defense Initiative, for which a total of $4.6 billion is requested. SDI has not fared well, however, at the hands of Congress. The Administration's requests have always been cut sharply. Last year, for instance, the request was for $5.2 billion, but Congress approved just $3.6 billion. It's a good bet that the programs will be trimmed back to less than $4 billion again for 1989.

The biggest part of the DOD development budget goes primarily for technology evaluation and testing of major tactical weapons systems. With more than a third of the total R&D request at $13 billion, tactical programs obviously include the big ticket items. Some projects that will be emphasized in fiscal 1989 include advanced antitank weapons for the Army, new tiltrotor aircraft development and antisubmarine warfare capabilities for the Navy, and work on munitions for hardened targets and various electronic warfare programs for the Air Force.

A feeling of déjà vu comes from development of launching equipment for the nearly complete MX, or Peacemaker, missile. Funds are being sought for development of a railroad garrison basing for the missile, a plan that had been debated heavily and rejected during the Carter Administration.

Apparently not affected by the budget ceiling agreed to in November is the Department of Health & Human Services, which puts almost all of its R&D money

TOTAL FEDERAL R&D BUDGET PROPOSAL

Obligations for R&D are up just 4% . . .

$ Millions	Obligations 1989[a]	1988[a]	1987[b]	Outlays 1989[a]	1988[a]	1987[b]
Defense	$36,787	$37,899	$36,088	$37,023	$33,776	$34,581
Health & Human Services	7,938	7,174	6,643	7,446	6,561	5,733
NASA	5,416	4,779	3,787	4,820	3,962	3,250
Energy	6,165	5,071	4,724	5,062	4,941	4,682
NSF	1,827	1,624	1,464	1,618	1,492	1,410
Agriculture	985	1,018	946	961	966	921
Interior	396	419	403	393	420	389
EPA	374	350	348	336	340	326
Transportation	317	325	322	341	352	324
Commerce	312	408	406	333	360	308
Veterans Administration	216	216	210	202	209	195
Agency for International Development	199	208	223	198	243	230
All other	585	560	527	563	539	513
TOTAL	$62,517	$59,951	$56,090	$59,318	$54,168	$52,862

a Estimate. b Actual. Source: Office of Management & Budget

. . . and basic research is up 6% . . .

$ Millions	Obligations 1989[a]	1988[a]	1987[b]	Outlays 1989[a]	1988[a]	1987[b]
Health & Human Services	$4,290	$4160	$3859	$4204	$3767	$3282
NSF	1,734	1439	1382	1526	1404	1329
NASA	1,374	1229	1014	1223	1017	865
Energy	1,265	1186	1061	1259	1175	1040
Defense	906	892	904	874	837	844
Agriculture	470	471	446	450	443	430
Interior	125	131	124	126	132	121
Smithsonian Institution	77	77	72	73	76	70
EPA	31	32	31	27	30	30
Commerce	27	27	26	26	25	26
Veterans Administration	18	18	17	18	16	16
All other	18	27	27	21	30	27
TOTAL	$10,335	$9689	$8963	$9827	$8952	$8080

a Estimate. b Actual. Source: Office of Management & Budget

. . . as are funds for R&D facilities

$ Millions	Obligations 1989[a]	1988[a]	1987[b]	Outlays 1989[a]	1988[a]	1987[b]
Energy	$1132	$ 939	$ 776	$1026	$ 918	$ 723
NASA	549	429	309	479	382	314
Defense	191	267	318	176	239	235
Agriculture	86	126	112	99	108	71
NSF	67	56	64	56	54	50
Health & Human Services	6	70	36	34	44	32
All other	58	75	63	57	66	39
TOTAL	$2089	$1961	$1679	$1927	$1811	$1464

a Estimate. b Actual. Source: Office of Management & Budget

into NIH. Last year, the Administration tried some accounting high jinks that effectively lowered the amount of research spending available to the huge biomedical establishment. However, Congress didn't go along with that idea, and so the proposed budget for 1989 is more straightforward. On paper, the HHS R&D budget is up 11% from 1988 to $7.9 billion, with the total NIH budget up 18% to ~~$7.8~~ billion, but total funding for the individual institutes is down 1% to $6 billion.

That will probably not be the case, because the Administration has pulled all of the funding for research on acquired immune deficiency syndrome (AIDS) out of each institute's budget and is asking instead for the funding in a separate account. More than $900 million of the $1.3 billion requested for AIDS research is expected to go to NIH.

Because AIDS research is now a separate line item, the budgets of some of the institutes, particularly Allergy & Infectious Diseases, appear to be sustaining large cuts. AIDS money presumably will flow back to these institutes, but how much is not indicated by the budget. In fiscal 1989, the Administration says NIH will be able to fund up to 21,000 research project grants and about 11,000 research trainees.

Unlike NIH, other research-supporting agencies within HHS get substantial cuts in their budgets. R&D funding for the Alcohol, Drug Abuse & Mental Health Administration, which got $561 million for R&D in 1988—mostly for clinical work on drug abuse and neurological disorders—is down to $522 million. For the Food & Drug Administration, which does only a little research relative to drug and food additive regulations, R&D funding is down 3% to $88 million. The Centers for Disease Control, which is responsible for much of the major epidemiologic research and health promotion in the U.S., is slated for a 12% cut in its R&D budget to $63 million.

Increased Administration emphasis on the space program this year has netted NASA its biggest proposed increase in many years with a total budget nearing $11.5 billion, about 40% of which is set aside for conduct of R&D. That $4.4 billion represents a 16% increase over fiscal 1988 appropriations. Most of the increase is expected to go to hardware development and plans for the space station. With a budget of almost $1 billion next year, an 87% increase over 1988, the space station is touted as an indispensable base for future manned lunar and Mars expeditions, either by the U.S. alone or in cooperation with other countries.

Many of the other programs NASA hopes to carry on depend on the resumption of space shuttle flights. Thus, some of NASA's fiscal 1989 R&D funds are going to the development of better expendable launch rockets, including a new advanced solid rocket motor for the shuttle. Flights are now scheduled to begin again in August, and NASA says it plans for seven missions to be flown in fiscal 1989 and maybe 10 in 1990. This schedule will allow for the launching of many of the astronomy and planetary missions NASA has had to postpone over the past two years.

Unlike HHS and NASA, the Department of Energy doesn't get an exemption from the November budget

DOE: Basic energy research big gainer

$ Millions	1989	1988	% change 1988-89
Defense R&D	**$2544.3**	**$2511.9**	1%
Weapons R&D, testing	1914.3	1904.9	0
Naval reactors development	630.0	607.0	4
Energy R&D	**3189.0**	**3100.6**	**3**
Basic science research	1713.3	1367.2	25
Supporting research activities	382.5	389.9	−2
Magnetic fusion	360.0	335.0	7
Nuclear energy	354.0	349.2	1
Fossil energy	168.0	354.1	−53
Renewable energy	124.9	149.0	−16
Conservation	86.3	156.2	−45
TOTAL	**$5733.3**	**$5612.5**	**2%**

Note: DOE has reorganized its R&D budget, comparable 1987 figures are not available; all numbers are estimates; obligations. **Source:** Department of Energy

NSF's total budget is up 19%. . .

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988-89
Mathematical and physical sciences	$ 502.8	$ 473.0	$ 464.7	6%
Geosciences	320.9	291.3	285.2	10
Biological, behavioral, and social sciences	288.7	266.0	259.3	9
Engineering	195.0	171.5	163.1	14
Science and engineering education	156.0	139.3	99.0	12
Science and technology research centers[c]	150.0			
Computer and information science and engineering	149.1	123.9	116.9	20
Antarctic program	141.0	124.8	117.0	13
Program development and management	95.5	84.5	77.8	13
Scientific, technological, and international affairs	51.0	44.0	43.8	16
TOTAL	**$2050.0**	**$1718.3**	**$1626.8**	**19%**

Note: Obligations. **a** Estimate. **b** Actual. **c** New program. **Source:** National Science Foundation

. . .while funding for the sciences is up 8%. . .

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988-89
Ocean sciences	$ 146.5	$135.4	$133.7	8%
Physics	126.7	118.2	117.0	7
Materials research	118.9	110.9	108.9	7
Atmospheric sciences	104.2	96.3	93.5	8
Chemistry	99.2	94.3	93.8	5
Astronomical sciences	90.0	86.0	85.0	5
Mathematical sciences	68.0	63.7	59.9	7
Biotic systems, resources	65.3	59.0	58.3	11
Earth sciences	59.3	51.3	49.9	16
Cellular biosciences	57.6	54.2	53.8	6
Molecular biosciences	48.3	44.6	44.2	8
Behavioral, neural sciences	46.5	43.8	43.3	6
Social, economic sciences	32.6	30.1	31.2	8
TOTAL	**$1063.1**	**$987.8**	**$972.5**	**8%**

Note: Obligations. **a** Estimate. **b** Actual. **Source:** National Science Foundation

. . . and for chemical programs up 7%

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988-89
Chemistry	**$ 99.2**	**$ 94.2**	**$ 93.9**	**5%**
Physical	28.5	28.0	28.2	2
Organic and macromolecular	22.8	22.4	22.4	2
Inorganic, bioinorganic, and organometallic	14.7	14.3	14.4	3
Analytical and surface	12.3	12.0	11.9	3
Special projects	12.0	9.1	7.1	32
Instrumentation	8.9	8.4	9.9	6
Materials research	**79.2**	**73.3**	**70.7**	**8**
Laboratories	26.9	26.2	26.6	3
National facilities	12.8	11.3	11.2	13
Solid-state chemistry	9.2	8.7	8.5	6
Materials research groups	8.9	7.4	6.0	20
Polymers	8.7	8.0	7.0	9
Ceramics and electronic materials	8.2	7.7	6.5	6
Instrumentation	4.5	4.0	4.9	13
Chemical, biochemical, and thermal engineering	**31.9**	**29.0**	**28.4**	**10**
Thermal systems	8.5	8.0	8.0	6
Interfacial, transport, and thermodynamic processes	5.6	4.7	4.6	19
Process and reaction engineering	4.0	3.7	3.6	8
Particulate and multiphase processes	3.6	3.3	3.3	9
Kinetics and catalysis engineering	3.5	3.2	3.1	9
Biochemical and biomass engineering	3.4	3.0	2.8	13
Separation and purification processes	3.3	3.1	3.0	6
Biochemistry	**14.0**	**13.3**	**13.7**	**5**
TOTAL	**$224.3**	**$209.8**	**$206.7**	**7%**

Note: Obligations. **a** Estimate. **b** Actual. **Source:** National Science Foundation

AIDS accounts for gains in health research

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988-89
National Institutes[c]	**$6051.5**	**$6081.8**	**$5677.5**	**−1%**
Cancer	1468.3	1469.3	1402.8	0
Heart, Lung & Blood	1015.5	965.5	930.0	5
General Medical Sciences	676.7	632.7	570.9	7
Diabetes & Digestive & Kidney Diseases	562.3	534.7	511.1	5
Neurological & Communicative Disorders & Stroke	557.6	534.7	490.2	4
Allergy & Infectious Diseases	435.1	638.8	545.5	−32
Child Health & Human Development	397.9	396.8	366.8	0
Eye	229.0	224.9	216.6	2
Environmental Health Sciences	218.9	215.7	209.3	1
Aging	204.8	194.7	177.7	5
Arthritis & Musculoskeletal & Skin Diseases	158.2	147.7	138.7	7
Dental Research	127.2	126.3	117.9	1
AIDS[d]	**1300.0**			
Research Resources	**320.0**	**368.2**	**322.9**	**−13**
National Library of Medicine	**70.6**	**69.6**	**61.8**	**1**
Center for Nursing Research	**24.4**	**23.4**	**20.0**	**4**
John E. Fogarty Center	**11.3**	**15.7**	**11.4**	**−28**
Research facilities	**5.0**	**47.9**	**31.9**	**−90**
TOTAL	**$7782.8**	**$6606.6**	**$6125.5**	**18%**

Note: Obligations. **a** Estimate. **b** Acutal. **c** Funds for AIDS research have been deleted from all Institutes and collected in the AIDS funding category. **d** Includes all Health & Human Services spending on AIDS, not just research. **Source:** Office & Management & Budget

Defense increase smallest under Reagan

$ Millions	1989^a	1988^a	1987^b	% change 1988–89
Conduct of R&D	**$37,880**	**$37,009**	**$34,877**	2%
Tactical programs	13,008	12,509	10,761	4
Strategic programs	6,605	7,162	7,817	−8
Advanced technology development	6,389	5,534	4,855	15
Intelligence and communications	4,499	4,797	4,802	6
Program management and support	4,068	3,866	3,825	5
Technology base	3,311	3,141	2,817	5
R&D facilities	**191**	**267**	**318**	**−28**
TOTAL	**$38,071**	**$37,276**	**$35,195**	2%

Note: Obligations. a Estimate. b Actual. **Source:** Office of Management & Budget

Space R&D moves ahead with new vigor

$ Millions	1989^a	1988^a	1987^b	% change 1988–89
Conduct of R&D	**$4382.7**	**$3793.3**	**$2943.5**	16%
Space station	938.6	502.0	309.5	87
Physics and astronomy	782.3	678.3	545.6	15
Space capability development	624.5	641.5	461.8	−3
Space applications	562.3	730.8	554.4	−23
Aeronautical research	409.9	358.2	382.4	14
Planetary exploration	400.3	350.3	346.2	14
Space research & technology	382.4	285.8	168.9	34
Life sciences	100.1	70.7	71.3	42
Transatmospheric vehicle	82.8	52.0	42.9	59
Commercial programs	58.7	88.3	31.9	−34
Safety & quality assurance	22.0	17.1	10.7	29
Tracking & data acquisition	18.8	18.3	17.9	3
R&D facilities	**285.1**	**178.3**	**217.4**	**60**
TOTAL	**$4667.8**	**$3971.6**	**$3160.9**	**18%**

Note: Obligations. a Estimate. b Actual. **Source:** Office of Management & Budget

Agriculture research is down 8%

$ Millions	1989^a	1988^a	1987^b	% change 1988–89
Agricultural Research Service	$577.0	$ 603.5	$ 522.3	−4%
Cooperative State Research Service	257.5	306.3	379.5	−16
Forest Service research	129.3	135.5	126.7	−5
National Agricultural Library	13.6	12.2	11.1	11
TOTAL	**$977.4**	**$1057.5**	**$1039.6**	**−8%**

Note: Obligations. a Estimate. b Actual. **Source:** Department of Agriculture

EPA research increases 6%

$ Millions	1989^a	1988^a	1987^b	% change 1988–89
Air	$ 72.5	$ 65.8	$ 63.1	10%
Superfund/underground tanks	67.6	59.2	40.6	14
Energy/acid rain	55.4	55.6	62.6	0
Hazardous waste	41.3	44.7	49.8	−8
Interdisciplinary	34.1	26.9	27.5	27
Toxic substances	26.6	26.8	31.0	−1
Water quality	25.1	24.8	25.1	1
Drinking water	22.0	22.5	22.8	−2
Pesticides	14.4	12.9	12.7	12
Management & support	11.8	10.1	11.0	17
Radiation	4.0	2.9	2.6	38
TOTAL	**$374.8**	**$352.2**	**$348.8**	**6%**

Note: Obligations. a Estimate. b Actual. **Source:** Environmental Protection Agency

ceiling agreement. Its total R&D budget at $5.7 billion is up the agreed upon 2%. The agency's budget for defense research programs is up just 1% to $2.5 billion, and that for energy research is up 3% to $3.2 billion. In addition, DOE will be spending $525 million that Congress already has appropriated on demonstration projects for innovative clean-coal technologies.

Among research programs whose budgets are down is basic energy sciences, funding for which is down 14%, or $62 million, to about $376 million, at least on paper. The cut is more than accounted for by DOE's continued refusal to ask for more funding for Congressionally initiated projects that the department doesn't want in the first place. Those account for some $73 million, which leaves room for increases in the programs DOE does want to support.

For example, operating expenses for the chemical portion of basic energy sciences programs, following an 11% increase in fiscal 1988, are up 6%, or $5 million, to $93.1 million in fiscal 1989. Just over 65% of that total supports work at national laboratories, and 31% supports university research. Funding for material sciences research is up 7%, or $8.6 million, to $135 million, following a 6% increase this year. Just under 75% of that budget goes to support work at national laboratories, with universities getting 24%.

Funding for DOE's basic research user facilities is soaring 69%, or $398 million, to $973 million, primarily because of the $363 million requested for construction and R&D on the Superconducting Super Collider. DOE says that "with continued funding as planned, the project can be completed in 1996."

However, funding for DOE university research support is not soaring. In fact it's down 14% to $15.8 million, and funding for university research instrumentation remains unchanged at $5 million. Even harder hit is funding for fossil energy R&D, down 53% to $168 million, and for conservation R&D, down 45% to $86.3 million. Congress has always refused to go along with cuts of this magnitude, but both budgets have slipped considerably over the past several years.

The budget request for NSF puts it back on track toward its goal of doubling funding over five years. The total budget is up 19%, or $332 million, to $2.1 billion. Obviously, NSF has the support of the Administration for its efforts, but it remains to be seen if Congress will also support it. NSF initiated this program last year with a requested increase of 17% for fiscal 1988. It got just 6%, or $91 million, and $40 million of that went to science education, leaving the research programs with a bare 3% increase.

For fiscal 1989, NSF wants a 10%, or $149 million, increase to $1.6 billion for its research programs. In addition, it is seeking $150 million for its new science and technology centers program as a separate line item in the budget. NSF says that this amount would provide upfront funding for about 15 centers for periods of up to five years. If that amount is factored into the research budget proposal, the resulting increase is 20%.

NSF points out that "because of the severe constraints imposed by Congressional reductions to the fiscal 1988 budget request, increases in award sizes, with few exceptions, were not possible, although support for graduate students through these awards was protected to the maximum extent." The reductions also forced deferral of needed purchase, upgrade, and maintenance of equipment. With the increase provided in the fiscal 1989 request, NSF says, attention will again be focused on individual investigator award size, support of students and technicians, and provision of needed equipment.

However, the NSF budget largesse doesn't extend to the chemistry division. Its budget is up only 5%, or $5 million, to $99.2 million. That comes after the less than 1%, or $436,000, increase it got for the current fiscal year. Within the division, funding for the traditional disciplines is up about 2%. Instrumentation monies are up 6%, which may not be enough to provide much support for the new initiative on funding of long-term maintenance and support for expensive instruments. However, funding for special projects is up 32%, or $3 million, to $12 million. This will allow the division to broaden the scope of its materials chemistry initiative as well as that of chemistry of life processes. Increases are also planned to fund the second year of the three-year postdoctoral fellowship program. And some money may well be available for chemical research from the science and technology centers account, if it is applied for.

Research spending by the Department of Agriculture's Agricultural Research Service is slightly higher in fiscal 1989, although a big cut in funds available for construction of buildings and facilities actually makes the total R&D budget about 4% less than in 1988. Budgets are also down for the Cooperative State Research Service and Forest Service research. Research on environmental concerns surrounding the use of pesticides gets significant increases in funding, including about $9.5 million in funds earmarked for reducing pesticide residues in foods, improving groundwater quality, and improving pesticide application methods. In addition, $700,000 is available for assessing the effect of reductions in stratospheric ozone on major crops.

Research grants administered through USDA's Cooperative State Research Service are increased 28% to more than $54 million, but work performed at a variety of federal research centers is zeroed out in the new budget. Research funds for work on animal health and disease, aquaculture, international trade issues, and productivity—amounting to nearly $50 million in cuts—at universities and colleges are eliminated on the basis that it can be done better through competitive grants.

Forest service competitive grants are also eliminated and other work reduced, cutting about $6.2 million from the research budget. Support continues for areas such as forest management, ecosystems interaction, insect and disease breakouts, and international trade and competitiveness.

Overall research funding at the Department of Interior is down 5%, or $23 million, to $396 million. Geological Survey research funding is down 5%, or $12 million, to $224 million. The remaining resources are devoted to, among other things, new improved methods of mineral exploration and improving the scientific basis for appraisal and evaluation of water resources. The research budget for the Bureau of Mines is down 10%, or $10 million, to $86 million, and for the Fish & Wildlife Services the budget is down about 7%, or $4 million, to $54 million.

At the Environmental Protection Agency, R&D has always had to take a backseat to the regulatory mandates set by Congress in the various environmental laws. The result sometimes has been wide-reaching regulations based on incomplete or even incorrect technical data. For fiscal 1989, R&D continues to be a small part of EPA's budget, although the President has proposed some increase.

Of the agency's total budget of nearly $3.3 billion (including administration of Superfund), $375 million is earmarked for R&D. This represents a 6% increase from fiscal 1988 spending of $352 million, but no major changes in direction for the agency. Unlike other R&D programs that have no specific goals, much of EPA's research is directed to meeting specific regulatory needs. As these are met, one program is slowed, and another takes its place. In 1989, research on drinking water is being reduced, for instance, reflecting the completion of toxicological testing of priority pollutants under the Safe Drinking Water Act. Funds for research on hazardous wastes are cut, but they really have been moved into the Superfund category, where they will be directed to devising better cleanup techniques for abandoned waste sites.

The greatest R&D spending by EPA continues to be in air research. Much of the research is aimed at expansion of work on stratospheric ozone depletion, but there will be some forward-looking research on the problems of global warming and assessing the risks of indoor air pollution. Research on radiation problems had almost been eliminated a few year ago, but because of the emphasis placed on radon leaking into homes, EPA has added more than $1 million for radon reduction technology demonstrations and measurements. EPA Administrator Lee M. Thomas says one of the agency's priorities in research this year is the reduction of uncertainties in human health risk assessments. Funded in the interdisciplinary category, about $10 million is devoted to giving a truer picture of health risks posed by environmental factors.

Research at the Department of Commerce is down sharply, almost 25%, or $96 million, to $312 million. Cuts in the National Oceanic & Atmospheric Administration's R&D budget account for more than the total reduction in the department's R&D budget; it is down $102 million, or 35%, to $180 million. This reduction is to be achieved by eliminating low-priority research programs such as seafloor spreading research, the national underseas research program, and the national Sea Grant College program. NOAA will devote $15 million to research to improve predictions of global climate change and maintain its acid rain research at current levels. The research budget for the National Bureau of Standards, also part of Commerce, is up 9%, or $10 million, to $120 million. ☐

Profits Rise Sharply For Canadian Chemical Companies

1987 ends with flourish for four major chemical firms, with combined earnings up 70% on combined sales rise of 20% in fourth quarter

"Best ever." "Record earnings." Those are the phrases that spice the 1987 fourth-quarter and annual earnings statements flowing out of the happy headquarters of many Canadian chemical companies.

For most of the Canadian chemical industry, 1987 was, indeed, a very good year. The notable exception, as in the past several years, is the fertilizer segment, and even that is starting to show some signs of improvement.

Chemical company profits benefited from a strong domestic economy, higher chemical exports, and long-awaited firmer prices. And the belt-tightening that most Canadian chemical companies put into practice during the lean years only a short time ago really paid off last year.

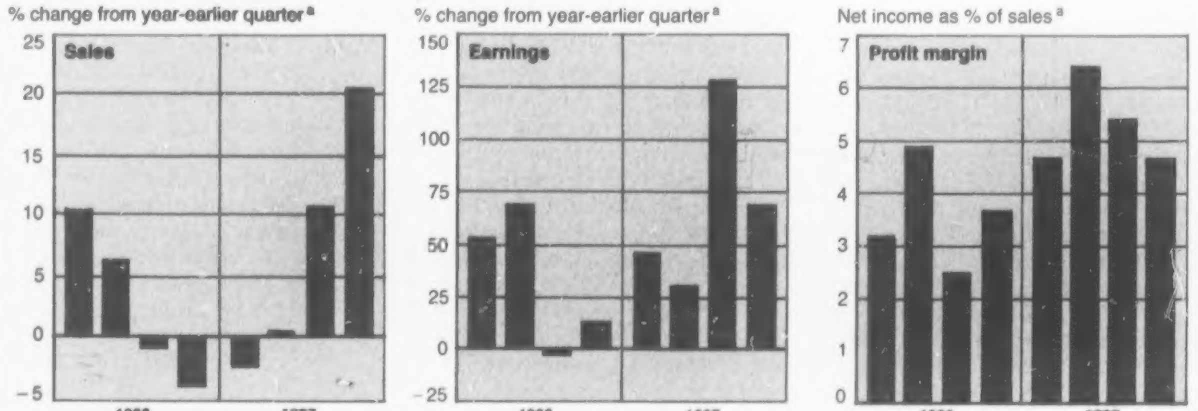
Even the stock market crash last October failed to make much of a dent in the fortunes of Canada's chemical industry. Fourth-quarter chemical sales were the highest of any quarter in the year. And profits rose a healthy 70% over the fourth quarter of 1986.

That, at least, is how the industry looks, based on combined results of the four large, publicly traded Canadian chemical companies tracked by C&EN. These companies are C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada. The cost-cutting measures and rationalization program implemented by Canadian chemical companies were particularly effective last year. For instance, combined sales of these four companies rose a respectable 20% to $711 million (all figures in U.S. currency; $1.00 = $1.311 Canadian) in the fourth quarter, but profits increased an even better 70% to $33.2 million. The story is the same for the entire year: sales up 6.7% to $2.61 billion ($1.00 = $1.324 Canadian) and profits up 55% to $139 million.

Of the four major firms, C-I-L turned in the most dramatic improvement last year, only in part because 1986 was not a particularly strong year for comparison. In 1986, C-I-L's net income dropped a hefty 49% from the previous year. Last year, it advanced an eye-opening 100%. The story is equally dramatic for the fourth quarter, when sales jumped 22% to $270 million and profits soared 700% from fourth-quarter 1986 to $6.1 million.

The company credits not only the economic recovery in several of its key markets, but a "growing payback" from the improvements in productivity and cost-reduction measures that it has implemented. For the entire year, sales were higher for all of the company's business units, with the usual exception of fertilizers. However, even fertilizer sales increased 16% in the fourth quarter.

Canadian chemical earnings shoot up faster than sales



Note: Combined results of C-I-L, Celanese Canada, Du Pont Canada, and Union Carbide Canada. a Based on Canadian currency

Canadian firms finish 1987 on a strong note

$ Millions[a]	Net sales	Change from 1986[b]	Net income[c]	Change from 1986[b]	Profit margin[d] 1987	Profit margin[d] 1986
	FOURTH-QUARTER 1987					
C-I-L	$270.1	22.1%	$ 6.1	700.0%	2.3%	0.3%
Celanese Canada	77.4	10.3	6.8	67.9	8.8	5.8
Du Pont Canada	273.8	18.8	14.3	29.7	5.2	4.8
Union Carbide Canada	89.4	29.2	6.0	61.7	6.7	5.4
TOTAL	$710.7	20.2%	$33.2	69.7%	4.7%	3.3%
	FULL-YEAR 1987					
C-I-L	$1011.7	3.9%	$ 30.2	100.0%	3.0%	1.6%
Celanese Canada	265.2	1.7	21.4	51.1	8.1	5.5
Du Pont Canada	1012.5	7.9	68.4	50.0	6.8	4.9
Union Carbide Canada	318.0	17.3	19.4	27.2	6.1	5.6
TOTAL	$2607.4	6.7%	$139.4	54.7%	5.4%	3.7%

a $1.00 = $1.311 Canadian (fourth quarter) and $1.324 Canadian (full year). b Based on Canadian currency. c Based on continuous operations and excluding extraordinary items. d Net income as percentage of sales.

For Celanese Canada, recently appointed president Paul H. Williams says that 1987 represented "the best performance in the company's 62-year history." Net income was up 51% from the previous year to $21.4 million on sales of $265 million, which were only 1.7% higher. He says that the strong improvement in earnings of the chemicals and industrial products group was responsible for much of the company's higher profitability. Volume and prices were higher in both domestic and export markets. At the end of the year, all plants were operating at full capacity. Fourth-quarter earnings increased 68% to $6.8 million on sales up 10% to $77.4 million.

Du Pont Canada also enjoyed record earnings in 1987, which president J. E. Newall attributes to a combination of higher sales volume, "modestly higher" selling prices, and "slightly lower" raw material costs. Together, these factors more than offset higher fixed costs and selling expenses.

Du Pont Canada's earnings rose 50% last year to $68.4 million, even though sales increased only 7.9% to just over $1 billion. Demand was exceptionally good for carpet fibers, specialty industrial fibers, engineering resins, and other high-performance plastics, Newall says. Earnings in the fourth quarter rose 30% to $14.3 million; sales, 19% to $274 million.

Union Carbide Canada also enjoyed a banner year in 1987. Sales were up 17% to $318 million and net income advanced 27% to $19.4 million. Fourth-quarter earnings climbed 62% to $6.0 million on sales up 29% to $89.4 million. Chemicals and industrial gases led the sales and earnings gains.

Canadian chemical executives are generally optimistic about 1988. However, any economic slowdown will prevent the industry from repeating last year's stellar performance. This doesn't mean that profits will not increase. It only means that the increase will not be so great as it was last year. Still, most Canadian chemical companies are in good shape to cope with an economic slowdown.

One factor that could hurt profits in the Canadian chemical industry is the growing strength of the Canadian dollar against the U.S. dollar. It now stands at 1.27 to the U.S. dollar, strengthening 8% in the past year. Some economists think that Canadian companies might be hurt if the Canadian dollar remains at this level. And there are signs that it could strengthen even more.

This could hurt Canadian chemical companies because about 62% of Canada's chemical exports move into the U.S., where a stronger Canadian dollar would make it tougher for them to compete against U.S. companies. Even those Canadian exports shipped to other parts of the world would find it more difficult to compete against U.S. companies exporting to the same destination.

Earl Anderson, New York

Sealants market to hit $2.3 billion by 1991

The U.S. market will consume some 1.5 billion lb of sealants worth $2.3 billion by 1991, according to a market report just released by Freedonia Group, a Cleveland-based business research organization.

The report puts U.S. consumption in 1986 at 1.3 billion lb, valued at $1.7 billion, and predicts a 2.8% per year growth rate between 1986 and 1991.

Fueling industry growth will be demand for new synthetic materials such as polyurethanes, silicones, epoxies, and fluorocarbons. The report predicts that demand for these sealants will grow nearly 7% per year through 1991. Older synthetics, such as synthetic rubbers, polysulfides, and acrylics, will exhibit about average growth—2 to 3%—through 1991. Demand for natural material sealants, such as linseed and oleoresinous compounds, however, will change little, if any, through the 1990s.

The new synthetic sealants are expected to do so well because of new applications and because of decreasing prices for the group. The older synthetics group continues to gain popularity while giving good performance at moderate price, according to the report. Natural sealants growth will be limited to existing uses, though they will remain the largest category because of their low cost.

The industrial market for all sealants will grow 3.4% per year through 1991, the report says, reaching 400 million lb that year; followed by the consumer market, which will grow 2.8% per year, reaching 480 million lb; and the construction market, which will grow 2.6% per year, reaching 630 million lb.

The resources of many small sealants firms will be strained by environmental issues, regulatory constraints, and enforced contributions to waste disposal programs, the report points out.

The 62-page report is available from Freedonia Group, 2940 Noble Rd., Suite 200, Cleveland, Ohio 44121, at a cost of $800.

Marc Reisch, New York

A1250-1
3/8/88

MARCH 7, 1988

CHEMICAL & ENGINEERING NEWS

AISLE 2700
AISLE 2600
AISLE 2500
2400
2300
MILTON ROY
Tracor

0511179C098 9 K AR0610SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

e

Instrumentation '88

Pittsburgh Conference
showcases analytical
trends in New Orleans
Page 27

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 10
CENEAR 66 (10) 1-84
ISSN 0009-2347

MARCH 7, 1988

News of the Week

- **Department of Energy has completed initial steps in its efforts to build a new production reactor for the U.S. nuclear arms program before problems with its current, aging reactors worsen. Page 6**

- **EPA's newly announced plan to protect groundwater from pesticide contamination establishes a framework in which states can tailor control measures to specific, local groundwater needs. Page 7**

- **Marking another new high in a continuing upward trend, foreign companies and inventors won about 47% of the patents awarded in the U.S. last year. Page 7**

- **A new "personal supercomputer" from Ardent Computer combines high computational speed with high-performance graphics. Page 8**

- **Samuel Heyman, chairman of GAF, has raised his bid to take over the company, but GAF's investment adviser is seeking higher bids from other parties. Page 8**

Cover: Photo by C&EN's Ward Worthy

Letters 4
Editor's Page 5

Concentrates

Business 9
Government 18
Science/Technology 23

The Departments

Books 62
ACS News 64
Newscripts 84

Business

West Germany's chemical industry will continue its steady performance, predicts Helmut Sihler, new head of its industry association. **Page 11**

Fiber Industries, a newly independent company formed from Celanese polyester fibers business, has a running start on success. **Page 13**

Developing countries now account for more than half of man-made fibers output, latest Enka survey shows. **Page 16**

Government

California's toxics law has taken effect and businesses are beginning to feel the impact. **Page 19**

Administration's 1989 budget proposal is a mixed bag for regulatory agencies. **Page 22**

Perkin Medal

James F. Roth is recognized for his outstanding contributions to catalytic chemistry. **Page 24**

Science

National Cancer Institute seeks contract proposals for preparation of radiolabeled materials, literature searching. **Page 25**

People

Roger J. Williams, noted biochemist and past ACS president, is dead at 94. **Page 66**

Instrumentation '88

At the 1988 Pittsburgh Conference in New Orleans, the conference's largest-ever exhibit featured many new lab products and the accompanying scientific sessions focused on advances in analytical methods. Page 27

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin: Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel *(Chairman); Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210, (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign, more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 83)

LETTERS

Plastic handguns

SIR: There have been many column inches expended in C&EN letters arguing against ACS members expressing their concerns about various matters in our news magazine (incidentally, one of the best in the business) on the grounds that it is inappropriate—I don't agree, but maybe so. One matter that ACS and all ACS members should be concerned about is plastic handguns. These can pass undetected through x-ray screens. Their only purpose is to kill or maim someone. They, along with plastic explosives, are uniquely possible as the results of the efforts of chemists.

The manufacture and importation of plastic handguns into the U.S. is supported by some gun manufacturers and the National Rifle Association. ACS should go on record as opposing this.

Alan C. Nixon
Berkeley, Calif.

Science teaching

SIR: Letters to the editor frequently point out that the education provided by the public schools leaves much to be desired, particularly in the sciences and math. As a retired scientist I do have time to do something positive. I am certain that others are also able and willing to donate some time in their own areas of expertise.

You can make as large or as small a contribution as your time available allows. Check with your local school principal and ask to meet one of the sixth- or seventh-grade teachers who would like help with a class science topic. My preferred way to help is to work with the teacher to develop an experiment or demonstration that the teacher can perform with the students. It thus becomes part of the teacher's continuing program that can be used year after year.

Once in a while I work directly with three or four students at a time on a new topic or demonstration to see what kinds of questions will need to have answers. I work only with the thought that the teacher will take the project over. This way I can go from teacher to teacher and project to project. The work is stimulating and I meet lots of interesting teachers and students.

It is important that the teacher initiate the request. I have found that my favorite projects often are of no interest to the teacher, so I just set them aside hoping some day they may be revived.

Occasionally, teachers want help in an area where I am not comfortable. When this happens, I look around among my friends and arrange for one of them to participate in the program.

If you get involved, be prepared for the following types of questions: What does a scientist do? What was your toughest course in school? Is math really important?

Don H. Anderson
Sequim, Wash.

Moissan celebrative volume

SIR: William B. Jensen, who reviewed "Fluorine: The First Hundred Years (1886–1986)" for you recently (C&EN, Nov. 30, 1987, page 28) was mistaken when he stated that the book comprises papers read at the Moissan centennial symposium held in Paris in August 1986. In fact, publication of the book, which was on sale at the symposium from the very first day, was a completely independent venture; and the objective, as stated in the preface, was both to present a history of the development of fluorine chemistry up to the end of World War II and to provide an up-to-date account of the subject from academic and technological viewpoints. Professor Jensen's query about the origin of the 13 appendixes in chapter 11 is easily answered: They were commissioned from well-known experts to provide truly authoritative information on aspects deemed to be specially important. Note that abstracts only of papers actually read at the Moissan symposium have been published in the *Journal of Fluorine Chemistry* [**35**, 3 (1987)].

R. E. Banks, *Manchester, U.K.*
D. W. A. Sharp, *Glasgow, U.K.*
J. C. Tatlow, *Birmingham, U.K.*

The new doctorate

SIR: Not to disparage the contributions of non-Ph.D. chemists, I would submit that Mario Altamura's suggestion (C&EN, Nov. 23, 1987, page 2) of a doctorate in chemical research would indeed do much to honor such persons. I would point out, however, that the doctorate carries with it the implication that the recipient not only can do original work but is willing to sacrifice nearly everything for it: six to eight years of practically uncompensated labor, if one counts the obligatory postdoc years; far more than 40 hours most weeks; and a near total lack of family life. Why create confusion by starting a new "doctorate"? For a similar contribution, anyone can have the real thing.

Robert M. Kuhn
Santa Barbara, Calif.

Developing nations lead man-made fibers output

Sooner or later it was bound to happen, and last year saw fulfillment of the expectation. For the first time, more than half of the global production of man-made fibers, and half of the synthetics, came from countries other than Japan, the U.S., and Western Europe together.

On a geographical breakdown, the U.S. now accounts for about 21% of the output of man-made fibers, Western Europe 18%, Japan 10%, and other countries—largely comprising China and those of Southeast Asia—the 51% balance. The synthetic fibers split is similar, with the U.S. having a 23% share, Western Europe 18%, Japan 9%, and the others 50%.

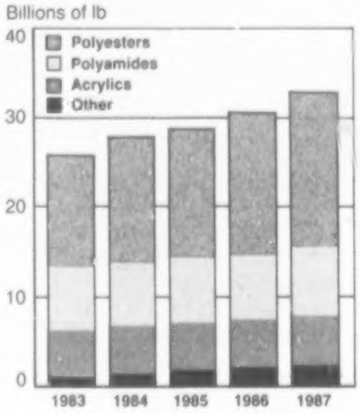
The data compiled by market analysts at Enka, the fibers arm of Akzo of the Netherlands, in their latest annual review of the world fibers scene, point up the shifting trend that has been taking place. Ten years ago, in contrast, countries other than Japan, the U.S., and those of Western Europe accounted for less than 35% of man-made fibers, and less than 30% of synthetic fibers.

Overall, last year saw continuation in global fibers' growth. The 39.89 billion lb produced was an all-time high. The 7% increase over 1986, one of the highest annual advances of the past decade, was helped by continued growth of textiles and clothing, and an upswing in the automotive trade, which in turn called for more tire cord to supply the original equipment and replacement tire demand. Production of synthetics—essentially acrylic, the nylons, or polyamides, and polyester fibers—which accounted for 82% at 32.65 billion lb, was up 8%.

The 7.24 billion lb of the cellulosic fibers—rayon, and the cellulose acetates—although nearly 3% ahead of 1986, came to only 18% of the total, down from 19% the previous year. Indeed, over the past 10 years, production of cellulosics has undergone a 1% or so average yearly decline from the 7.82 billion lb in 1977, whereas that of the synthetics grew nearly 5% a year from 20.47 billion lb.

The Enka review makes the point that the 6% growth in cellulosics was entirely accounted for by the "other countries," where almost 60% of all cellulosic fibers now are made. The "western" industrial countries showed a slight decline. Moreover, staple was the only cellulosic fiber for which there was an increase, shifting gradually to the "others," to India and Indonesia in particular; filament showed a slight drop. "The persistently high demand for [cellulosic] filament yarn could not be met for all textile sectors," the study notes.

Polyester fibers continue to dominate output



Source: Enka

Output of man-made fibers in the U.S. advanced 6% from 1986 to 8.51 billion lb, reflecting improved domestic demand due to the persistently strong textiles market. In addition, exports benefited from the fall of the dollar's exchange rate against major world currencies. The result was a substantially higher use of capacity.

In Western Europe, however, man-made fibers production moved marginally down to 7.11 billion lb. In Japan, it slipped more than 1% to 3.78 billion lb, largely because of a fall in exports, and a rise in textiles and clothing imports. Competition with Japan's neighboring Southeast Asian countries intensified. Rest-of-the-world production was up a sizable 12% to 20.5 billion lb. As for

Man-made fibers output reaches all-time high . . .

Billions of lb (% change from previous year)	1987	1986	1985	1984	1983	1977
U.S.	8.51 (6.2%)	8.01 (3.4%)	7.75 (−2.1%)	7.92 (−1.5%)	8.04 (−15.5%)	8.07 (10.2%)
Western Europe	7.11 (−0.1)	7.12 (−1.7)	7.24 (2.3)	7.08 (5.2)	6.73 (5.8)	6.88 (−4.5)
Japan	3.78 (−1.3)	3.83 (−3.8)	3.98 (0)	3.98 (2.6)	3.88 (1.6)	3.77 (5.9)
Other	20.49 (11.7)	18.35 (8.8)	16.87 (8.3)	15.57 (12.3)	13.87 (6.4)	9.77 (9.1)
TOTAL	**39.89 (6.9%)**	**37.31 (4.1%)**	**35.84 (3.7%)**	**34.55 (6.2%)**	**32.52 (7.8%)**	**28.29 (5.5%)**

. . . mainly as a result of growth of synthetics

Billions of lb (% change from previous year)	1987	1986	1985	1984	1983	1977
U.S.	7.51 (7.3%)	7.00 (2.8%)	6.81 (−1.3%)	6.90 (−1.4%)	7.00 (17.3%)	6.86 (11.0%)
Western Europe	5.82 (0.3)	5.80 (−0.9)	5.85 (5.6)	5.54 (6.5)	5.20 (8.3)	4.76 (−6.0)
Japan	3.02 (−0.7)	3.04 (−2.9)	3.13 (2.3)	3.06 (3.7)	2.95 (1.4)	2.85 (6.0)
Other	16.30 (13.2)	14.40 (11.0)	12.97 (10.3)	11.76 (15.1)	10.22 (9.5)	5.99 (14.1)
TOTAL	**32.65 (8.0%)**	**30.24 (5.1%)**	**28.76 (5.5%)**	**27.26 (7.4%)**	**25.37 (10.3%)**	**20.46 (6.7%)**

Source: Enka

annual change during the recent 10 years, that for the U.S. at less than 1% just about equaled Western Europe's, Japan showed essentially no movement, and the other countries had a gain of nearly 8%.

Among the synthetic fibers, 57% of last year's global total production consisted of staple fiber, 43% was filament yarn. The split was the same as in 1986, but differed from 10 years ago when about equal quantities of the two forms were made.

The 7.51 billion lb of synthetic fibers made in the U.S. was an improvement of more than 7% on 1986. Europe's 5.82 billion lb was only slightly up on 1986, and still below 1985's quantity. Japan retreated for a second consecutive year to 3.02 billion lb, nearly 1% down from 1986. The other countries registered a solid 13% growth to 16.3 billion lb. Viewed over a 10-year span, production in the U.S. grew barely 1% a year, but did better than Japan's 0.6% rate. That of Western Europe, a more respectable 2%, was far outpaced by the other countries' more than 10% yearly increase in output.

Among the synthetics, polyester fibers continue to pull ahead of the rest. At 16.98 billion lb last year, they made up 52% of the total production against their 51% (15.43 billion lb) 1986 share, and 46% (9.41 billion lb) in 1977. The nylons, at 25% (8.16 billion lb in 1987), are next in volume importance, but their slice of the total has been moving down over the years. In 1977, for example, their share stood at 31% (6.34 billion lb) of synthetics made that year.

Likewise the acrylics, which last year made up 17% (5.55 billion lb) of the total, have been losing ground, but not to the same extent. Their 1977 share was 19% (3.89 billion lb).

Other synthetic fibers, mainly the elastomerics and those based on polypropylene and polyvinyl chloride, made up the 6% 1987 balance at 1.96 billion lb. In 1977, these held a 4% (820,000 lb) niche.

The U.S. continues to hold the lead in nylon and polyester fibers production among the western industrialized countries. In fact, its 34% share (2.77 billion lb) of world nylons output is up from the 22% share (1.39 billion lb) in 1977. But Western Europe's moved down to 17% (1.39 billion lb) from 34% (2.16 billion lb), and Japan's to 7% (570 million lb) from 11% (700 million lb) in the same period. Other countries had the 42% (3.43 billion lb) balance of nylon production, compared with the 33% (2.09 billion lb) they could claim in 1977.

As for polyester fiber, last year's production breakdown was 21% (3.57 billion lb) in the U.S., 11% (1.87 billion lb) in Western Europe, 8% (1.36 billion lb) in Japan, and 60% (10.19 billion lb) in the rest of the world, helped to a large extent by expansions in China and Taiwan. The 1977 production profile was 39% (3.67 billion lb) for the U.S., 17% (1.60 billion lb) for Western Europe, 13% (1.22 billion lb) for Japan, and 31% (2.92 billion lb) for the remainder.

In acrylic fibers, the U.S. is at the bottom of the league with 11% (610 million lb) last year, compared with 32% (1.78 billion lb) for Western Europe, 16% (890 million lb) for Japan, and 41% (2.28 billion lb) shared throughout the rest of the world. Ten years ago, the U.S. and Japan tied at 17% (660 million lb) behind Western Europe's 36% (1.40 billion lb), and the other countries' 30% (1.17 billion lb).

Regarding the current year, the Enka analysts confine their outlook to the West European scene. They foresee a slackening in automotive sales, which in turn will impact on tire sales, especially original-equipment tires. And the "slight increase" expected in the demand for textiles and clothing "may primarily benefit imports." Although Western Europe's domestic demand for the man-made fibers industry "may firm up slightly, export conditions will continue to be poor," they believe.

Dermot O'Sullivan, London

Evolutionary

MEL-TEMP II®
A new generation of the MEL-TEMP melting point apparatus. Teamed with our optional electronic thermometer, the new MEL-TEMP II achieves state of the art accuracy. $295.00

CHEM-DRY®
A durable, integrated chemical dryer. Superior to Abderhalden dryers. Unique design permits removal and storage of samples without breaking vacuum and risking exposure. $395.00

LABORATORY DEVICES
Box 402C, Holliston, MA 01746-0402, U.S.A. (617) 429-1716, (508) 429-1716 after 7-16-88

CIRCLE 32 ON READER SERVICE CARD

plant in Carson, Calif., that produces detergent products, will be affected by Proposition 65 at this time, Bartolanzo says. The facility uses benzene, one of the 29 chemicals now covered by the law, and emits small amounts of the chemical. At the facility's fence line, the concentration in the air is on the order of 30 ppb, she says, which is well below the workplace standard of 1 ppm.

Nevertheless, "erring on the side of caution," Monsanto is posting warning signs around the perimeter of the Carson plant, Bartolanzo says. The company is also placing advertisements in several local newspapers that state that small amounts of benzene are emitted by the facility while stressing that the emissions meet or are below permitted levels.

New groups of chemicals will fall under Proposition 65's warning provision each quarter beginning in July. On Oct. 27 this year, the law's provision prohibiting discharge of listed chemicals into drinking water will take effect for the first group of 29 chemicals. The regulations governing that aspect of Proposition 65 are still being formulated. ☐

Regulatory agencies' '89 budget a mixed bag

The fiscal 1989 budget proposal that President Reagan presented to Congress late last month is a mixed bag for the regulatory agencies that, in one way or another, interact with the chemical industry.

For instance, the Environmental Protection Agency's regulatory budget is up 10%, or $220 million, to $2.3 billion, following an almost 30% gain for the current fiscal year. But that doesn't mean increases for every program. For example, funding for the toxic substances program has been cut almost in half to $41 million. The largest portion of the reduction, according to the agency, reflects a decision not to request any more money for removing asbestos from school buildings. EPA notes that the federal government has already provided more than $150 million to fund abatement projects that have greatly reduced the problem. Any further activities, it says, should be the responsibility of state and local governments.

Funding for drinking water programs is down almost 10% to $54 million. Still EPA says that in fiscal 1989 it will promulgate standards for 34 toxic chemicals and radionuclides, including radon, the last of the 83 contaminants specified in the Safe Drinking Water Act Amendments of 1986.

In sharp contrast is the pesticides program budget, which is soaring by more than $50 million to reach a total of $86 million. All of the increase, however, will go to fund the transportation, storage, and disposal of canceled and suspended pesticides. That activity is currently funded at $8.4 million. According to EPA, the large increases in 1989 will enable it to make significant progress on final disposal of dinoseb and 2,4,5-T/Silvex.

In the legal area, EPA's enforcement budget is up 7% to $299 million, and funding for the Justice Department's environmental enforcement activities is up 23% to $32 million. Funding for the antitrust division is up 12% to $294 million.

The Occupational Safety & Health Administration's budget, on the other hand is up just 4% to $245 million, following a 3% increase this year. OSHA says it will issue seven health standards in fiscal 1989, up from six this year; increase its number of inspections from 62,200 to 66,500; and issue eight safety standards, double the number planned in the current fiscal year.

The Food & Drug Administration's budget is falling 2% to $467 million, following a 7% increase for fiscal 1988. Hardest hit are FDA's drug activities. That budget account is down 10% to $175 million, at a time when the agency is under pressure to expedite the approval of new drugs, particularly ones developed to combat acquired immune deficiency syndrome.

Janice Long, Washington

EPA's regulatory budget is up 10% . . .

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988–89
Superfund	$1632.4	$1440.3	$ 987.6	13%
Hazardous waste	161.1	156.0	152.2	3
Water quality	146.1	146.8	165.6	0
Air	119.2	115.7	124.2	3
Pesticides	85.7	35.0	25.6	145
Drinking water	54.0	59.1	57.6	−9
Leaking underground storage tanks	50.0	39.4	20.3	27
Toxic substances	41.3	77.5	75.2	−47
Interdisciplinary	9.6	9.4	6.3	2
Radiation	7.2	7.9	4.0	−9
TOTAL	$2306.6	$2087.1	$1618.6	10%

. . . OSHA's just 4% . . .

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988–89
Enforcement	$158.3	$150.5	$146.5	5%
Federal	117.0	110.0	86.7	6
State	41.3	40.5	59.8	2
Compliance assistance	36.1	35.3	35.0	2
Safety and health	26.9	26.5	24.1	1
Statistics	20.2	20.0	17.4	1
Standards	6.7	6.5	6.5	3
Technical support	17.5	16.6	16.4	5
Administration	6.0	5.8	6.0	3
TOTAL	$244.6	$234.7	$228.0	4%

. . . and FDA's down 2%

$ Millions	1989[a]	1988[a]	1987[b]	% change 1988–89
Drugs	$174.7	$194.0	$176.5	−10%
Foods	132.3	126.4	120.4	5
Devices and radiological products	77.8	74.9	71.0	4
Program management	57.2	56.5	54.1	1
National Center for Toxicological Research	25.0	24.3	23.0	3
TOTAL	$467.0	$476.1	$445.0	−2

Note: Obligations. a Estimates. b Actual. Source: Office of Management & Budget

A1250-1
3/8/88

MARCH 14, 1988

CHEMICAL & ENGINEERING
NEWS

0511179C098 9 K AR6611SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Farming in Europe

Changing policies bring hard times to fertilizer makers
Page 7

Volume 66, Number 11
CENEAR 66 (11) 1–44
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

MARCH 14, 1988

News of the Week

- **New thallium-containing copper oxide becomes completely superconducting at a record 125 K.** Page 4

- **Amendments to the Clean Air Act, if enacted, would increase pollution expenses for industry at least $32 billion a year, says Business Roundtable.** Page 5

- **Koppers Co., a Pittsburgh-based construction materials and chemicals producer, is resisting takeover by British construction firm Beazer.** Page 5

- **Former refuseniks, recently allowed to emigrate, gathered in New York City to thank U.S. scientists for their efforts and to urge backing for scientists still in the U.S.S.R.** Page 6

- **This Thursday India's high court will rule on whether Union Carbide should pay $270 million in interim compensation to victims of the methyl isocyanate leak at its Bhopal plant.** Page 6

Cover: "The Cornfield," painted in 1826 by John Constable. Reproduced with permission of the National Gallery, London

Letters 2
Editor's Page 3
Concentrates
Business 13
Government 18
Science/Technology 21
The Departments
ACS Comment 27
People 43
Newscripts 44

Business

Quantum Chemical, new name of National Distillers & Chemical, marks change to petrochemicals and energy firm. **Page 15**

Government

Impact on U.S. firms of lax intellectual property laws in foreign countries is detailed in new survey, which will be used by Administration to push for stronger protection. **Page 19**

Science

Effort to map the entire human genome is backed by the National Research Council, which recommends that a 15-year, $200-million-a-year project to accomplish that goal begin immediately. **Page 22**

National Academy of Engineering elects 85 engineers to academy membership, including several in chemically related areas. **Page 26**

ACS News

ACS has initiated a multimillion-dollar fund-raising drive to expand several activities of the society. **Page 28**

News Focus

In light of recent stagnation in the fertilizer industry, European manufacturers are especially concerned about impending revisions in European Community agricultural policy that might reduce fertilizer demand. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle; Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign, more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 43)

LETTERS

Education in chemistry

SIR: The letter by Rustum Roy (C&EN, Jan. 18, page 3) prompts us to respond to certain issues and concepts relating to both education and funding.

First, we find to link the current "disastrous national debt" in any way with the meager funds expended by the National Science Foundation makes no sense.

Second, on the issue of graduate education in chemistry, we feel that any move to an applied science basis can be accommodated only to a limited degree. The basic level of training at our undergraduate institutions leaves much of the basics of chemistry still to be learned, and much of the value of our present programs is aimed in that direction through course work, examinations, tutorials, and the teaching of basic experimental techniques. Compared with many other countries, our B.S. majors have taken little chemistry and need the extra curriculum. This difference originates in part from the shorter training period dedicated to chemistry in the U.S. compared with some countries that Roy praises. Is it not also true that some of the research described by Roy as "esoteric" and "inward looking" could be equally well described as "concerned with establishing new fundamentals?"

Third, although we agree that we do need to teach more courses at the graduate level that are relevant to industry and are interfacial with other disciplines, we feel it is unreasonable to expect that our graduate programs could or should be aimed at totally applied problems. Science as a whole grows and feeds on new discoveries, and if we could predict where, when, and how these discoveries could be made, industrial research would surely have solved all that is needed to be known. It was the discovery of ferrocene, for example, that indirectly led to the use of chromocene supported on silica as the Union Carbide catalyst for the polymerization of ethylene. Could this have been predicted? And did the physicist predict that so-called 1-2-3 oxides would be high-temperature superconductors?

If the National Science Foundation does not continue to fund basic chemistry, this country will lose its leading role in chemistry and essentially lose its graduate programs in chemistry. Only from a strong and broad background can chemists respond to current issues of national interest. The maturity of molecular design and electronic structure places the chemist in a prime position to contribute to the rational design of new materials in the same way that a sound knowledge of physical organic chemistry coupled with an arsenal of synthetic methodologies allows for success in the area of the synthesis of natural products and new pharmaceuticals. We suggest that the currently structured graduate chemical education is successful if it is viewed as an apprentice system that teaches problem solving via one specific scientific project. Subsequent self-study on topics new to the fresh Ph.D. is inevitable during the course of a 30-plus-year scientific career. Versatility and flexibility in job responsibilities are key traits sought in the industrial hiring process.

With the need thus established for such versatility, the question now moves to Roy's reluctance to "fund more chemists out of the materials pot." Given the need to deal constructively with the current chemistry faculty population, we suggest that federal incentives together with the "Kennedy-esque call" (to serve one's country) are perhaps quite effective ways to influence the future research and teaching creativity of our present teachers.

Kenneth G. Caulton
Malcolm H. Chisholm
Indiana University

Contributions to glossary

SIR: The IUPAC Commission on Physical Organic Chemistry (III.2) is working on a revised and extended edition of the "Glossary," edited by the late Victor Gold and published in *Pure & Applied Chemistry* [**55**, 1281 (1983)]. It is desirable that this revision takes into consideration as much as possible the opinion of the scientific community, and all scientists interested in this project are invited to contribute.

Comments and criticism on the first edition of the "Glossary," suggestions for the revision as well as copies of the correspondence exchanged with Victor Gold on this matter should be mailed to the chairman of Commission III.2, Paul Müller, Department of Organic Chemistry, University of Geneva, 30, quai Ernest Ansermet, CH-1221 Geneva 4, Switzerland.

P. Müller
President, IUPAC
Commission on Physical
Organic Chemistry

ers think they are more stable than the 1-2-3 compounds, which degrade on standing in moist air.

The newest superconductors also may turn out to be easier to process into useful shapes. But precautions will be necessary because thallium is toxic: Its sulfide, for instance, is used as rat poison.

The recent upheavals in superconductivity research caused by the discovery of the bismuth and thallium materials have stunned and exhausted researchers, Engler says. But "we're all happy," he adds, because "it has reminded us that this field is still full of surprises." The rise in transition temperature, coming after many unsubstantiated reports of superconductivity at much higher temperatures, also has rekindled scientists' optimism that room-temperature superconductivity is achievable, he says.

Ron Dagani, Washington

Business group blasts changes in clean air bill

Business Roundtable has released a detailed analysis of the costs that would be imposed on industry by amendments to the Clean Air Act currently being considered by the Senate. If enacted, the changes would increase pollution control expenses for industry at least $32 billion a year above present costs and eliminate at least 300,000 to 600,000 U.S. jobs, according to the analysis.

The numbers are higher than, but within the same range as, estimates by the Congressional Research Service (up to $28 billion) and the Environmental Protection Agency (about $24 billion).

"This bill would be the most expensive environmental legislation ever adopted and the least cost-effective," says David M. Roderick, chairman of Business Roundtable's environmental task force and of USX Corp. (Business Roundtable is an association of some 200 major corporation executives that acts on public issues.) "If it were enacted, total annual environmental control costs would exceed $100 billion, about 2.5% of the gross national product." Furthermore, notes Roderick, the bill would add up to 8.6% to the cost of many industrial products, harming U.S. competitiveness in international trade.

The bill, S. 1894, was introduced last year by Sen. George J. Mitchell (D.-Me.) and reported for floor action by the Senate Committee on Environment & Public Works last November. Titled the "Clean Air Standards Attainment Act of 1987," the bill would put areas into compliance that do not meet present standards, and provides for acid rain control, new fuel and emissions standards, and more rigorous control of industrial releases of toxic chemicals into the air. Business Roundtable believes the bill targets unachievable air quality goals.

The association's analysis was prepared by the consulting firm R. M. Dowd & Co. of Washington D.C. Only 21 of the 43 provisions in the bill were amenable to cost estimates. It is impossible to quantify expenses such as increased costs of automobiles to consumers, the report concludes, because technology to meet the proposed standards doesn't exist yet.

Estimated additional costs for the chemical industry fall into three areas. Emissions of nitrogen oxides and volatile organic compounds from process plants would have to be cut to attain ozone standards. Emissions of sulfur dioxide must be controlled to meet the acid rain provisions. And a variety of controls would be needed to reduce releases, both controlled and accidental, of a class of hazardous chemicals. The report estimates costs to the chemical industry of $2 billion to $9.5 billion a year.

David Hanson, Washington

Clean air changes would greatly raise industry costs

$ Millions	1985 output value	Costs due to S. 1894	% of output value
Aluminum production	$ 2,000	$ 134	6.7%
Chemicals	193,453	4337	2.2
Copper & lead smelting	1,460	126	8.6
Food	310,584	678	0.2
Iron & steel	33,000	818	2.5
Motor vehicle production[a]	179,195	1446	0.8
Petroleum production	86,639	1029	1.2
Petroleum refining & sales	141,511	9096	6.4
Pulp & paper	75,423	1609	2.1
Rubber	21,224	566	2.7
Textiles	51,282	636	1.2

Note: Comprises cost estimates only for 18 of the 43 provisions in the proposed law. a Includes stationary sources only.
Source: Business Roundtable

Koppers under siege from British builder

In one of the latest moves in the corporate takeover game, Koppers Co., Pittsburgh-based construction materials and chemicals producer, has received a takeover bid from investment group BNS Inc., led by British construction firm Beazer, for $45 per share, or $1.3 billion. Although Koppers has not yet officially commented on the proposal, it is evident that the company's management will resist the offer at that price.

In a letter to Koppers chairman Charles R. Pullin made public last week, Brian C. Beazer, chairman and chief executive officer of the British firm, pointed out that he had attempted to arrange meetings with Pullin on three separate occasions. Beazer also stated in the letter, "It remains our desire to enter into a negotiated transaction and to determine, among other things, whether a higher price is, or is not, warranted."

Wall Street, in its own way, is helping Koppers resist the offer by keeping the company's stock price high. And Beazer's statement that he may be willing to raise the price is adding to Wall Street's resolve. Following the offer by Beazer, the price of Koppers' stock soared more than $6.00 per share. Since that time it has held in the $52 to $53½ range, about 15% more than the Beazer offer price. Obviously, arbitrageurs are expecting either an increase in the offer price from Beazer or a competing offer from another company.

The construction materials side of Koppers probably interests Beazer most. The British company has been working to build a fully integrated construction firm, acquiring in the

Changes in European Farm Policies Trouble Fertilizer Industry

In the face of growing payments to farmers and increasing food surpluses, the European Community is looking at ways to control these problems—but proposed solutions could reduce fertilizer use

Patricia L. Layman, C&EN London

European fertilizer makers have long memories. They remember when, shortly after World War II, European governments exhorted their farmers to "Dig for Britain" or for France or Belgium or wherever else, uprooting trees or hedges, if needed, to raise more and more food and grain to feed a war-wracked populace. Fertilizers were a respected partner in that effort.

They also recall specific instances of government policy determining courses of action that would affect their industry. For example, as little as 10 years ago, the European Community's agriculture mavens encouraged farmers to grow rapeseed as a good cash crop that would help cut seed-oil imports. It also happens to be a heavy feeder, requiring significant use of fertilizer.

But how things have changed. The community, saddled nearly to the point of bankruptcy with steadily mounting payments to farmers and faced with food surpluses that have become an embarrassment, is trying to cut back. As EC's policies, and those of its member nations, change, there undoubtedly will be a long-lasting impact on the fertilizer industry. Unfortunately, it will be an impact not needed: Fertilizer makers are already facing long-term prospects of stagnation at best, with shrinkage more likely. Exports, always a significant part of the business, are decreasing, and imports are increasing, competing for a bigger share of a shrinking pie. All this makes fertilizer a victim of its own success.

The crux of EC's problem is its Common Agricultural Policy, a set of complex price supports that has materially raised the standard of living for most of the 10 million farmers in the community. However, the policy features few controls, and farmers have continued to increase production to increase their support benefits beyond the actual needs of Western Europe.

Lonza photo

Agricultural fields near Swiss village of Hermiswil

By the end of this month, officials of the European Commission—the administrative arm of the European Community—will begin working out new agricultural price proposals for the next marketing year. Meeting in Brussels, agriculture ministers from each member nation will begin to tackle a handful of thorny proposals to change European agriculture, including proposals on how to do it and on how it should be supported by government.

The ministers face three possibilities for change:

- A simple, market-driven philosophy: Let prices

Cadmium and nitrates from fertilizers cause environmental concerns

There is growing awareness throughout Western Europe about the impact fertilizers have on the environment. One concern relates to cadmium, a natural component in phosphate rock. Another centers on the nitrate content of drinking water. Some countries are further along than others in formulating laws on permissible levels of cadmium and nitrate release. And moves have been under way in Brussels toward drawing up standards for the 12 European Community member countries.

Cadmium is highly toxic, causing death of some forms of water life at concentrations of 0.1 ppm or less. It tends to accumulate in organisms over a period of time because it isn't readily eliminated.

Awareness of the health risks associated with cadmium isn't new. The element has been linked to the death and considerable physical discomfort of Japanese who ate contaminated rice grown in paddies irrigated with industrial wastewater (C&EN, Aug. 10, 1970, page 15). It is on the black list of substances cited in the framework convention for the protection of the Mediterranean Sea against pollution sponsored by the United Nations Environment Program (C&EN, Feb. 28, 1977, page 17). And the World Health Organization (WHO) has recommended that the provisional weekly intake by humans shouldn't exceed 400 to 500 µg.

Fertilizers aren't the only source of cadmium released to the environment. Cadmium is also a component of batteries and tires, pigments and stabilizers, metal platings, and the powders in fluorescent light bulbs. It also occurs in gaseous effluents from incineration plants and coal-fired power stations.

In fertilizers, the amount of cadmium varies greatly from one source of phosphate supply to another. Deposits in Finland, the Soviet Union, and South Africa are lowest in cadmium, typically 3 mg per kg of the phosphate (P_2O_5) content, or even less. Jordanian rock has from 15 to 30 mg per kg of P_2O_5. Cadmium in U.S. phosphate rock varies from about 20 to 120 mg per kg of P_2O_5. Comparable levels for other countries where the rock occurs are 40 to 120 mg per kg of P_2O_5 in Morocco, 50 to 100 in Israel, 140 to 170 in Togo, and 220 to 280 in Senegal.

The rock's cadmium ends up in phosphoric acid and in the active ingredients of fertilizers made from it. Diammonium phosphate produced in the U.S., for example, can have from 20 to 80 mg per kg of P_2O_5, that supplied by Tunisia 75 to 100. In the case of triple superphosphate, material from Morocco and Tunisia may contain as much as 120 mg per kg of P_2O_5.

Denmark, Finland, the Netherlands, Sweden, and Switzerland are in the forefront of setting limits on the amount of released cadmium tolerated. Denmark aims to reduce the cadmium limit in fertilizers in stages, from 200 ppm this year to 50 ppm in 1998. Finland has a limit of 30 ppm of cadmium in fertilizer.

Authorities in the Netherlands are concerned because the mean weekly cadmium intake by the population is about 175 µg, notes Wim Sprong at the Ministry of Housing, Physical Planning & Environment in The Hague. "That means that possibly too many people are above the WHO recommended limit," he points out. "One of the problems is that we don't know precisely the form of the distribution curve."

Because cadmium is fairly easily taken up by crops, it is assimilated by dairy cattle, Sprong notes. The contention is that about half of that cadmium comes from fertilizers, half from both wet and dry deposition. "Since about 60% of the waste here in Holland is incinerated, this is an important cadmium source," he says. He admits, however, that the widespread use of cadmium by industry would make a reduction in the wet and dry deposition rates "virtually uncontrollable."

His ministry is tackling the problem on two fronts. One forbids use of plastic consumer products with cadmium used in pigments and stabilizers, and of metal items plated with cadmium. The other seeks to lower the permissible level of fertilizer cadmium ultimately to 15 ppm on the P_2O_5-content basis from the present mean value of 70 to 80 ppm.

Apart from using low-cadmium phosphate rock, supplies of which aren't sufficient to meet all the fertilizer producers' needs, the as-yet unanswered question is how best to extract the cad-

fall enough, as they would for a crop in gross surplus, and farmers would then stop producing that particular crop. Politically, this is a totally unrealistic option, which even rigorous economists in the industry concede, and it has little or no chance of being adopted.

- Stabilizers on price supports, to try to cap expenditures. Supports would be at a set level, up to a fixed quantity. If farmers collectively were to go beyond that, they would receive only world prices—generally substantially lower than those supported by EC. In a way, points out one economist, stabilizers are a modified form of price reduction. But they enable EC to avoid reducing supports themselves. The high payments can continue, up to a point, to maintain high agricultural prices and incomes—politically very important in rural areas.
- Set-asides. The U.S. has practiced this policy for years—compensating farmers for taking some land out of cultivation to reduce total yields. Whether it works or whether farmers try to boost production from the remaining acreage probably is not really important per se. What is more important is that even if it does work, it doesn't solve the problem of surpluses overnight. Any such program, once adopted, must be looked upon as a long-term commitment.

EC has agreed to adopt some sort of stabilizer pricing. In addition, the commission almost certainly will impose some sort of set-aside program. It sees set-asides as part of a general scheme of "extensification," officially defined in community rules as a reduction in a farmer's output of a surplus product by at least 20% without other surplus production capacity being increased. As such it has seriously directed member governments to come up with specific proposals for set-aside programs, with the intention of reaching an agreement by the middle of this year. As an information mium from fertilizer raw materials. Some companies are exploring calcination techniques, trapping the cadmium in the flue gases. Others are looking into use of ion-exchange resins to remove cadmium from phosphoric acid.

Although such techniques might work at bench scale or even the pilot plant level, there is some question about their technical and economic feasibility in commercial plants. Should suitable methods be devised, there will remain the problem of ultimate disposal of the cadmium. There would be a financial incentive to recover it if the current high market price for cadmium were to remain in force.

There is no doubt that cadmium removal will add to the cost of fertilizers, Sprong concedes. He thinks that a 10% or so price increase might be sufficient to pay for the added processing steps. For this reason alone, he and others believe it is important that there be a Europewide agreed limit to the permissible cadmium content of fertilizers.

Responding to the groundswell of concern, the Commission of the European Community has proposed an action program to control environmental pollution by cadmium. Last December, the EC Council of Ministers issued a resolution noting that "such control should be pursued through an integrated approach, taking into account all the various sources of cadmium pollution." Among the major elements of the strategy for cadmium control, the resolution calls for "stimulation of research and development related to the cadmium content of the raw materials used for production of phosphate fertilizers."

The EC Commission also has moved on setting recommended limits on nitrate ion content of groundwater and drinking water. Its 1985 directive, titled "Quality of Water for Human Consumption," sets a maximum admissible concentration of nitrates at 50 mg per L, down from an earlier level of 100 mg per L, with a guide level of 25 mg per L. This permissible maximum relates to every water sample analyzed, not to an average of readings.

Legislators' concerns about nitrate are twofold. One relates to a condition called methemoglobinemia, a blood disorder more usually associated with babies younger than six months. Referred to as blue baby syndrome because the skin turns blue, it is caused by the inability of blood to carry adequate quantities of oxygen when deoxygenated hemoglobin is irreversibly oxidized to methemoglobin, which cannot hold oxygen. Nitrite ions stemming from nitrates are a causative factor. Fortunately, the disease is extremely rare, and virtually nonexistent in Western Europe for the past 20 years or so.

Seemingly, a high nitrate level in ingested water alone doesn't bring it about. An accompanying bacterial infection, such as gastroenteritis, is involved, notes a just-completed detailed study of the health implications of nitrates in water. The study was made by a Europewide panel of experts drawn together by Brussels-based ECETOC, the European Chemical Industry Ecology & Toxicology Center.

"There is no evidence that infantile methemoglobinemia is caused by bacteriologically sound water supplies containing nitrate concentrations up to 100 mg per L," the report concludes. It adds that "98% of the European population is supplied by piped-mains water treated to remove bacteriological contamination. The remaining 2% is supplied with well water of variable quality."

The other cause of concern is the suggestion that nitrates might lead to development of stomach cancer in humans. The proposed pathway is that nitrate-derived nitrite ions interact with amines to form nitrosamines, which have been linked with the onset of cancer. This theory doesn't appear sound in light of the decline in the incidence of stomach cancer despite increasing nitrate levels. Moreover, in the case of the U.K., deaths from stomach cancer are lowest in the East Anglia region even though that region has one of the highest water nitrate levels in the country.

In light of the essential absence of health risks, the ECETOC study concludes that "Recent reductions in the acceptable upper limit for nitrate in drinking water from about 100 to about 50 mg per L [are] not justified."

Dermot O'Sullivan, London

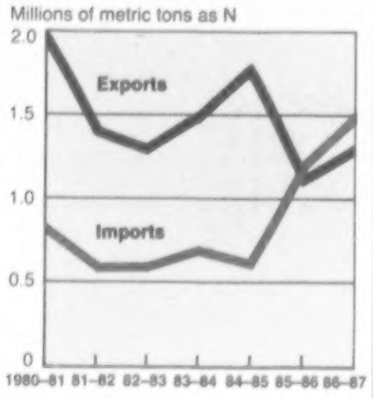
memo from Brussels put it in January, "In order to respect farmers' freedom of choice, the proposed scheme must be optional. However, in order to be effective, it must be mandatory for member states in the sense that each country will be obliged to introduce it."

The proposal has met with mixed success. In France, farmers generally support the idea, provided the set-aside land can be turned to livestock—a potential problem because some livestock are in surplus. And in West Germany, the state of Schleswig-Holstein has adopted a set-aside program already, although for only 10% of arable land.

In the U.K., the Ministry of Agriculture, Fisheries & Food last December circulated proposals for meeting the EC request to such groups as the National Farmers' Union, the Country Landowners' Association, ancillary industries such as fertilizer makers, and fringe pressure groups including Greenpeace, organic farming lobbies, and others. Comments were due on Feb. 2, the goal being to send a workable program to Brussels by June.

Comments and numbers on the ministry's proposals show where the problems will be. The U.K. proposal would offer a farmer the opportunity to set aside a minimum of 20% of his or her land. The proposed level of compensation would be $266 to $354 per hectare, or $108 to $143 per acre ($1.00 = £0.565 on March 4, 1988).

However, that level of compensation might not be enough to bring about the desired reduction. According to one industry analyst, "We know the margins producers achieve and their costs of production. Margins of the bottom 25% producers are much higher than those proposed." Costs, he calculates, are equivalent to roughly $265 per acre. If machinery running costs of $50 per acre are assumed, this indicates that the incentive needs to be about $215 per acre for the farmer to break even.



European nitrogen fertilizer imports exceed exports

Source: Industry estimates

At the proposed prices, farmers would be worse off, unless they could save fixed costs (machinery and labor). A 20% reduction in area wouldn't do that in a meaningful way. A farmer can't have 20% less of a tractor, for instance. Working on the assumption that one farm worker and a tractor can handle 250 acres, a farmer would need to have a base of 1250 acres to cut one worker and one tractor. However, an average cereal enterprise has only 110 acres.

A recent survey by consultants Cambridge Farm Management found that in cereals, the major surplus concern, the most marginal production is spring barley, not wheat, and wheat is the main surplus. Moreover, spring barley as a crop is concentrated in certain parts of the country, primarily Scotland, which would lead to a concentrated, localized uptake of the scheme. That leads to another question: If barley is taken out of Scotland, what would that mean for Scottish distilleries?

Other industry observers ask about alternative uses for the set-aside land. Some suggestions have included golf courses and other similar recreational uses, but these could realistically take only a small proportion of what would be a lot of land. "The only real alternative is forestry," argues one analyst, "but unless that is subsidized, the economics are crazy. In the meantime, how are farmers to live? It'll just mean more major government subsidies." Forestry as an alternative would also mean that farmers would need a long-term commitment to a set-aside program, if only because it takes a long time for trees to grow and for farmers to recoup their costs.

With its interests set on the set-aside program, the European Commission elected not to consider the problem of the density of livestock stocking—the number of head of livestock for a given area of land. But countries in Western Europe, both inside and outside EC, have decided the subject is a fit one for consideration.

It basically is a means of controlling what one newspaper wag has dubbed the latest "mountain"—the "muck mountain"—with the concern being nitrate contamination of underground water supplies. As more and more livestock have been raised throughout the community, there has been more and more manure produced, more than needs to be spread on the farmers' own fields. The consequences involve either direct runoff into water systems or overabundant spreading on land, with subsequent leaching of nitrates into the water. This is a particular problem in the Netherlands, Denmark, Switzerland, and West Germany.

The Dutch and Danish governments and the cantonal government in Lucerne, Switzerland, have introduced laws that essentially control stocking levels: a farmer will be allowed only so many hogs, beef, or poultry for given quantities of land. If he currently has more, he will have to get rid of the excess, or, in the Swiss variation at least, come up with a contract showing that someone qualified will purchase the extra manure and take it away. The Dutch government also plans to impose a levy on surplus manure.

With competing nitrogen from organic sources and from the set-asides, what does this mean for the fertilizer industry? Says Stuart J. Challinor, senior business economist for ICI Fertilizers, "In the U.K., cereals are 50% of the nitrogen market. In theory, a 20% set-aside could mean a reduction of 10% [in nitrogen fertilizer demand]. It could be as simple as that. That wouldn't happen, though, because you would see some intensification of what's left, and some fertilizers for golf courses and forestry."

Nonetheless, even part of a 10% decline in business, combined with the reduced production that a program of price support stabilizers would lead to, would be the last thing the fertilizer industry needs. For now, it is also coping with a rather dreary long-term outlook, following hard on the heels of the beating it has taken over the past several years.

At the International Fertilizer Forum in Antwerp in November, sponsored by British Sulphur Co., Pertti Laurilla, business development executive with Finnish fertilizer producer Kemira, highlighted some of the recent trends in the industry. Nitrogen use increased until the early 1980s in Western Europe, but it has leveled off in the past couple of years. For phosphorus and potash, there has been no growth since the early 1970s, and during the past few years, "consumption has even been declining," he said.

Slightly less than 30 million metric tons per year of nitrogen-phosphorus-potassium (NPK) fertilizers, including blends, are used in Western Europe, he said—a figure that has remained practically unchanged for many years. Although consumption has remained static, significant changes have been occurring in the structure of the industry itself.

These changes were given a special boost by the industry's 1986 economic losses. William Klaassen of Dutch producer DSM told the Antwerp meeting that in 1986 fertilizer producers in Western Europe had expected difficulties and even poor results. But no one expected the actual results—aggregate losses throughout the industry of roughly $500 million.

Those conditions spurred a boom in the merger and acquisition activity that had started at the beginning of the decade. As Klaassen put it, "For some, it was a rude awakening to the basic elements of economic forces, the need to constantly improve or perish. No longer could the lame lead the blind."

Norsk Hydro—which had acquired Dutch fertilizer company NSM, the second largest in the Netherlands, in 1979, and the fertilizer division of the British pharmaceuticals company Fisons, in 1982—kept building by buying. In 1985, the Norwegian company acquired the fertilizer operations of Veba in West Germany, which it has continued to operate under the name of Ruhr-Stickstoff, the second largest producer in West Germany. And in 1986, Norsk Hydro acquired 80% of the shares of Cofaz, the second largest fertilizer producer in France, which is Europe's biggest fertilizer market.

Finnish producer Kemira had already acquired Danish fertilizer company Superfos to solidify its base in the Nordic countries. It then went straight into the major European markets by acquiring Carbochim and Sadacem, subsidiaries of Belgian producer Gechem. The acquisition gave a good push toward doubling Kemira's business in fertilizers.

ICI in the U.K. and Nitrogin Eireann Teoranta in Ireland combined interests, and ICI also consolidated its hold on Scottish Agricultural Industries, buying the remaining outstanding shares of the Scottish fertilizer company. And France's tangled agricultural industry got a bit of sorting out as various units were pulled together under the aegis of CdF Chimie.

Western Europe's fertilizer use overtakes that of North America

Millions of metric tons per year	1986-87ᵃ	1985-86	1984-85	1983-84
EASTERN EUROPE				
Nitrogen	16.7	16.2	15.4	15.6
Phosphate	11.2	10.7	9.8	9.6
Potassium	10.2	10.1	9.5	9.5
WESTERN EUROPE				
Nitrogen	10.6	10.3	10.1	9.9
Phosphate	4.8	4.9	5.1	5.2
Potassium	5.0	5.2	5.3	5.3
NORTH AMERICA				
Nitrogen	9.9	10.7	11.7	11.2
Phosphate	4.2	4.5	5.0	5.2
Potassium	4.7	5.0	5.4	5.6
DEVELOPING COUNTRIES				
Nitrogen	32.5	31.4	31.8	29.0
Phosphate	11.6	10.9	11.8	10.5
Potassium	4.8	4.5	4.6	3.9
TOTAL WORLD				
Nitrogen	**71.2**	**70.0**	**70.5**	**67.1**
Phosphate	**33.9**	**33.1**	**34.0**	**32.0**
Potassium	**26.1**	**25.6**	**25.9**	**25.4**

a Estimated. **Source:** West German Fertilizer Association

Industry observers generally feel that there is still a bit of tidying up to do. The Spanish fertilizer industry, for example, is currently in the throes of restructuring. And there are continual reports that, in Italy, there will be talks by Fertimont (the fertilizer arm of Montedison) and Enichem to pool interests.

However, the industry now stands with a handful of major companies dominating the Western European market: Norsk Hydro, ICI, BASF, DSM, Kemira, and CdF Chimie. DSM's Klaassen reached the following conclusions: "There are not many further mergers to be expected, and all these remaining producers, without doubt, intend to stay in the fertilizer business in one way or another."

The mergers and capacity retirements have certainly helped the industry. Though not alone responsible for improved results, things have been picking up a bit. For example, in 1987, Norsk Hydro's agricultural group had operating income of $163 million ($1.00 = 6.27 Norwegian crowns on Dec. 31, 1987) on sales of $4.55 billion, compared with a loss of $87.2 million on sales of $4.51 billion in 1986. The improvement was strongest for the agricultural group's fertilizer activities, the company said.

On the other hand, when H. B. van Liemt, chairman of DSM's board of management, announced profit estimates at Christmas, he said that performance in the agricultural group was disappointing and that this would limit group profit growth for the year. Rationalizations within the agro division during 1987, he said, had had a beneficial effect, but there was still room for further improvement.

And when Denys Henderson, chief executive officer of ICI, announced the company's annual results in late February, he made a similar point. The company's fertilizer operations lost less, albeit on lower sales, than in preceding years, he said—a loss of only $7.5 million ($1.00 = £0.530 on Dec. 31, 1987), compared with a $40 million loss in 1986. Fertilizer sales were $1.6 billion, down from $1.7 billion in 1986. Despite the cut in the losses, however, he added, "We will go on hacking away at parts of that business."

One factor affecting the industry is the arrival of urea into EC from six countries at dumped prices. In October 1987, product coming from Austria, Hungary, Malaysia, Romania, the U.S., and Venezuela was the subject of a new antidumping probe by the commission (C&EN, Oct. 19, 1987, page 14). EC fertilizer makers claimed that urea from these countries quadrupled to 414,000 metric tons in just three years, an increase in the EC market share from 3.6% to 12%. Also in 1987, EC imposed antidumping duties on urea from Libya and Saudi Arabia, and set limits to the quantity coming from Czechoslovakia, East Germany, Kuwait, the Soviet Union, Yugoslavia, and Trinidad and Tobago.

The imports continue to come in. Moreover, fertilizers from other producers will continue to eat into the markets that Western European manufacturers traditionally have exported to.

As Karl-Heinz Tillmann, director for fertilizers at

BASF, puts it, "New countries supplying nitrogen fertilizers are coming up, countries where energy is worth [costs] almost nothing, and with a small or no home market."

A case in point is Saudi Arabia. Late last month, Saudi officials confirmed plans to build a new world-scale, export-oriented ammonia plant at Al Jubail, using one of two options—a 500,000 metric ton-per-year plant based on off-gas feedstock, or a conventional ammonia unit of the same capacity. Saudi Arabia already has one 500,000 metric ton-per-year ammonia plant intended for use in downstream fertilizer plants being built for the National Chemical Fertilizer Co., Ibn Al-Baytar. These will include a 500,000 metric ton-per-year urea plant in the first phase, to be followed by a plant of the same size for NPK fertilizers, one roughly half that size for triple superphosphate, and a 30 metric ton-per-day plant for liquid nitrogen-phosphorus fertilizers. These plants will eventually supply the export market.

China and India remain the major import-receiving countries, despite each country's efforts to build up its own industry. But they haven't yet caught up and still need imports, as does most of densely populated East Asia. The next largest export market is Central and South America; then Africa. Africa, with a population expected to reach 1.25 billion by the year 2030, needs fertilizers the most and is least able to afford them.

With the change in trade patterns has also come changes in products. Blends of fertilizer have become increasingly important, as local or regional bulk-blenders have been able to buy ingredients freely on the spot market to mix and sell. According to Kemira's Laurilla, bulk blends now hold 10% of the West European share of the NPK market. Some individual countries show much higher proportions. In Ireland, for example, bulk blends account for 85% of the market, and in the U.K. they account for 30%. However, speaking at the Antwerp meeting, Laurilla predicted that in 10 years they will account for no more than 15% of the Western European market because of a number of adverse factors, such as uncertainties in prices of "commodity" intermediates, poorer quality of blends compared with homogeneous granules, and the market's requirements for a higher level of technical support than bulk-blenders are sometimes able to provide.

Security of supply, high quality, and a high level of service are all marketing points that fertilizer makers can latch onto to help build and retain market share.

The competitive strategy of Lonza, for example, has involved an emphasis on service. Lonza is the dominant Swiss supplier of fertilizers but a very small player in the European marketplace as a whole. Why does it stay in? Says Franz Indra, a group leader in the company's agrochemicals unit, the company's fertilizer operations go back nearly to the turn of the century, when it turned its production of calcium cyanide from acetylene to production of fertilizers. "We were one of the first companies with ammonia and nitric acid for ammonium nitrate," he says. The company even had a urea plant, but he adds, "When the petrochemical industry really took off, there we were with a 25 ton-per-day urea plant, and suddenly other plants were 1000 tons per day. We decided to restrict ourselves strictly to the Swiss market—we were not competitive elsewhere."

Considering that Swiss government policy requires that Swiss farmers produce enough food for the country in times of crisis (such as war), the country must use fertilizers. Therefore, Indra says, "We need a Swiss fertilizer industry. Our ammonia is based on hydrogen from naphtha, so therefore we need to have naphtha—But would we, in war? We have an agreement with the Swiss government to keep our water electrolysis plant operational, so we could switch [to electrolytic hydrogen] if needed."

Lonza is helped to be competitive because the government requires importers to keep inventories of 60% of annual sales, a requirement Lonza doesn't have to meet. Additionally, says Indra, although Lonza can't compete on price alone, with the soil and crop analysis system it has devised, "If we give farmers products exactly designed for their plant and soil needs, we have a chance to compete. It is niche marketing. We are optimistic and convinced we can stay in the fertilizer business. We can stay the predominant supplier in Switzerland. We can give a service, selling a philosophy, a system. We won't get rich, but it makes sense for Lonza to stay in the business."

Major producer ICI emphasizes service (such as special analysis programs for farmers) and continual work on process improvement. The company feels it has a winner, for example, with its AMV ammonia process. Two new plants featuring it are due to start up this year in Britain. The process permits smaller plants—probably about half the size of the 500,000 metric ton-per-year standard—with capital costs less than half the typical $175 million or so the bigger ones cost. That makes the process appealing during periods when a company can't justify enormous capital expenditures.

And it is service and attention to business details that BASF looks to for keeping the company successful in the business. "The industry is in a structural crisis," says Tillmann. "In 10 years, we know there will be less fertilizer used [in West Germany] than today, because of cutting back on overproduction of crops, and improved efficiency. There is no replacement for fertilizers; they are a plant food, and you always need that. But you can't sell more. Our obligation is not to produce more, but to produce less, much cheaper—just the opposite from most big-volume chemicals.

"To stay in the business, you have to have good locations, technology, interchange with operations, access to markets, and a need to be in the business. So it's just a question of how much a company wants to stay in, and stay in with up-to-date technology. We're looking at the fertilizer business over [the next] 20 years or more. You must, if you want to continue in the business."

It is also, he adds, a matter of maintaining that partnership with the rest of the agricultural community. "We must help the farmers find the solutions to go on farming." ◻

High Cost to U.S. Firms of Lax Intellectual Property Laws Detailed

Government aims to use data, which show piracy of patents, trademarks, and copyrights in foreign nations is big problem, to push for greater protection

A report from the International Trade Commission provides new data on the losses U.S. companies face from inadequate protection of their patents, trademarks, and copyrights in foreign countries. The Administration hopes to use this new information in its push for a multinational pact providing stronger intellectual property protection.

Released at the end of February, the ITC report is the result of a year of analysis. U.S. Trade Representative Clayton Yeutter requested the study in January 1987, and ITC held a public hearing in May. According to Yeutter, "The failure of our trading partners to provide effective protection for intellectual property is a severe and growing problem that distorts trade." The bulk of the report is devoted to results from an extensive survey of U.S. companies in a variety of industries on how they have been affected by foreign patent and copyright laws.

The survey questionnaire was mailed to 736 U.S. firms, including the 500 largest firms in the U.S. and others identified as relying heavily on intellectual property protection. ITC received 431 responses, and 269 of these said that intellectual property was of more than nominal importance to their business.

The survey shows that U.S. companies are losing business in several ways because of inadequate intellectual property protection. In some countries, for instance, patent laws explicitly exclude some inventions from being patented. Pharmaceuticals often fall in this category. Patent terms may be far shorter than in developed nations. Compulsory licensing requirements, extremely narrow patent claims, and unrealistic requirements on when a patent must be used are other sources of concern in certain countries.

Yeutter: U.S. will move aggressively

Trademarks face similar problems. Often the scope of what constitutes trademark infringement is far too narrow, and renewal of proof that a trademark is still valuable is difficult. Copyright problems account for some of the biggest losses, much of them in the entertainment industry. ITC reports that many countries have no treaty relationship with the U.S. to make U.S. works eligible for copyright. In addition, some countries only protect certain kinds of works, or have a lot of exceptions to use.

An area important to the chemical industry that is becoming an increasing problem is protection of trade secrets. Many nations seem to have a very short term for keeping data confidential, usually through conditions placed on technology transfer, ITC says. And, there is often no legal protection against the use of trade secret information by third parties because an agreement may only be enforceable between the two original parties.

The upshot of all of this is that ITC estimates U.S. companies lost as much as $61 billion in 1986 because of poor intellectual property protection. Although the number is high, it was not unexpected. Mark

International piracy costs industries billions of dollars

$ Millions, 1986	Lost sales	Lost exports	Lost fees, royalties	Lost employment
Building materials	a	$ 153.4	$ 10.5	478
Chemicals	$123.2	507.3	103.9	1327
Computers & software	a	704.8	235.2	1328
Electronics	292.8	1571.2	15.9	478
Industrial & farm equipment	323.5	126.0	13.0	550
Petroleum refining	a	52.0	38.5	a
Pharmaceuticals	16.2	270.0	231.9	0
Scientific & photographic equipment	1.3	3.1	33.0	a
Textiles & apparel	178.5	26.5	46.5	603

Note: Includes only the companies that responded to the survey. Not all companies in a category answered all questions or provided loss estimates. a Data not provided because it was deemed confidential or inadequate.
Source: International Trade Commission

D. Estes of the ITC General Manufacturers Division and principal author of the report, says that estimates of more than $20 billion had been made for some time. Also, in 1984, ITC issued a report on the impact of counterfeit products imported into the U.S. that concluded that counterfeits cost U.S. manufacturers more than $8 billion annually.

Estes says that data could not be collected regarding specific problems within individual industries, although he says the chemical and pharmaceutical industries are well represented. At least 32 companies in the chemicals and allied products area, and another 20 in pharmaceutical and health care products that sell both in the U.S. and abroad, were involved in the survey. Other chemically related industries were petroleum and refining, rubber products, textiles and wearing apparel, cosmetics and fragrances, and scientific equipment. Some calculation of total aggregate losses for 1986 within these groups was made by ITC. Scientific and photographic equipment makers estimate losses totaling $5.0 billion, pharmaceuticals $1.9 billion, chemicals $1.3 billion, and petroleum refining (including plastics) $1.3 billion.

ITC recognizes that attempts to quantify effects of weak or nonexistent intellectual property laws pose difficulties. Statistics on sales and export losses from violating goods are not collected, for instance. And companies may simply avoid a market if they believe property rights will be ignored. So, ITC says that its data are only good for the companies responding and cannot validly be used statistically to project to all of U.S. industry. Still, the data highlight significant points of concern.

The questionnaire also asked companies to identify and rank the countries that are causing the biggest problems. More than 160 companies responded by naming 67 countries and Hong Kong, including 14 that were thought to have an impact of more than $100 million each. These are, in descending order by estimated losses, Taiwan, Mexico, South Korea, Brazil, China, Canada, India, Japan, Nigeria, Hong Kong, Saudi Arabia, Indonesia, Italy, and Spain. Most of the losses were because of piracy in electronics, computers, recordings, and tapes.

Estes believes that some of these countries are trying to make amends. South Korea and Taiwan have passed tougher intellectual property laws recently, for instance, but it will be a while before it can be determined if these laws are being enforced. The number of complaints about Taiwan has been decreasing recently, Estes says, indicating that some efforts are being made there.

Data from the report will be used by Yeutter to negotiate multilateral agreements for better protection with the offending nations. And if that doesn't work, Yeutter says, the U.S will move "aggressively on a bilateral basis." The subject has been under discussion since early rounds of the international trade talks last year. One incentive for nations to strengthen their laws is to remain on the generalized system of preference with the U.S. GSP, as it is called, is provided to encourage industrial development in developing countries, and, in the case of the U.S., often means being allowed to import products without duty. Loss of GSP could affect a country's exports significantly. According to Estes, good progress is being made on a bilateral agreement in patent and copyright protection. Still, Yeutter says, "It's not just developing countries. There is ample opportunity to improve things among most of the nations of the world."

David Hanson, Washington

Federal Alert—new legislation

This C&EN listing highlights legislation introduced between Feb. 10 and March 3. Senate and House bills are listed under subject areas by bill number, primary sponsor, and committee(s) to which referred.

SENATE

Environment. S. 2060—Dixon (D.-Ill.). Provides $14 million over three years to help communities meet radium standard for drinking water; Environment & Public Works.

S. 2066—Roth (R.-Del.). Bans ocean dumping of municipal sludge by end of 1988, permits five-year waivers for communities currently dumping that have system design and schedule for ending dumping; Environment & Public Works.

S. 2091—Durenberger (R.-Minn.). Gives states authority to design and implement programs to control sources of groundwater contamination under guidance of EPA, requires protection of all groundwater; Environment & Public Works.

S. 2106—Bradley (D.-N.J.). Directs Bureau of Reclamation to assess existing water projects to determine their effect on groundwater quality and quantity, technologies for groundwater recharge; Energy & Natural Resources.

Patents. S. 2111—Hatfield (R.-Ore.). Prohibits patenting of genetically altered or modified animals; Judiciary.

Research. S. 2086—Mitchell (D.-Me.). Provides $29.5 million over five years for creation of 10 multistate, regional marine research centers; Environment & Public Works.

S. 2107—Kassebaum (R.-Kan.). Authorizes USDA to construct plant science and education center at Kansas State University, Manhattan, in accordance with USDA review team's recommendations; Agriculture, Nutrition & Forestry.

Taxes. S. 2092—Durenberger (R.-Minn.). Imposes new taxes on hazardous waste disposal, solid waste disposal, provides for water supply assessment, and excise tax on pesticides sold in lawn/garden market to finance groundwater protection program; Finance.

HOUSE

Environment. H.R. 4074—Hughes (D.-N.J.). Imposes fees on ocean disposal of municipal sludge, prohibits disposal after Dec. 31, 1991; Merchant Marine & Fisheries.

H.R. 4090—Ray (D.-Ga.). Delays for one year the requirement that owners and operators of underground storage tanks have minimum of $1 million insurance coverage per potential occurrence of a leak; Energy & Commerce.

H.R. 4096—Walgren (D.-Pa.). Requires EPA to prescribe standards for all above-ground storage tanks with capacity greater than 4200 gal that contain regulated substances; Energy & Commerce.

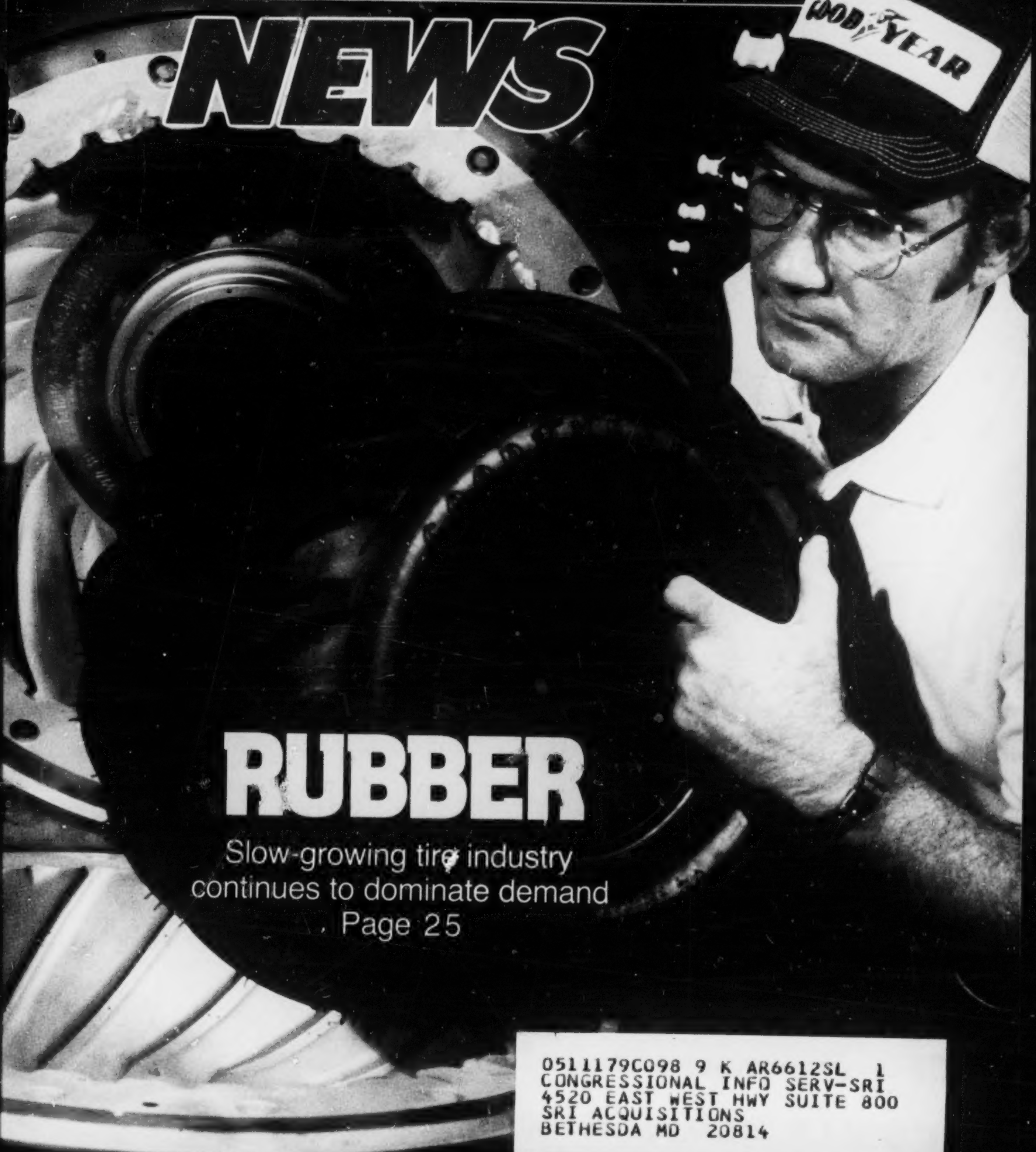
Patents. H.R. 4086—Kastenmeier (D.-Wis.). Sets forth basis for determining whether a person has engaged in conduct constituting misuse or illegal extension of a patent; Judiciary.

Testing. H.R. 4046—Gray (D.-Pa.). Prescribes testing employees of refineries, nuclear power plants for use of alcohol, controlled substances; Energy & Commerce.

A1250-1
3/23/88

MARCH 21, 1988

CHEMICAL & ENGINEERING NEWS



RUBBER

Slow-growing tire industry
continues to dominate demand
Page 25

0511179C098 9 K AR6612SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 66, Number 12
CENEAR 66 (12) 1–78
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

MARCH 21, 1988

News of the Week

■ NASA study provides first strong evidence for serious ozone depletion outside Antarctica, places blame on chlorofluorocarbons. **Page 6**

■ Henkel Group's U.S. subsidiary has named a new president and launched an extensive reorganization program. **Page 7**

■ Claims against Monsanto's Searle unit over infections allegedly caused by Searle's discontinued Copper-7 birth-control device could escalate as a result of new evidence in a St. Paul, Minn., court case. **Page 7**

■ EPA has opted not to review the carcinogenic potential of the herbicide 2,4-D, drawing praise from Dow Chemical and criticism from environmental groups. **Page 8**

■ House subcommittee hearings on plans to build the Superconducting Super Collider probe funding of project, raise questions about extent of foreign support. **Page 8**

Cover: All-terrain vehicle tire is removed from mold at Goodyear's Madisonville, Ky., specialty tire plant

Letters 4

Concentrates
Business 9
Government 13
Science/Technology 17

The Departments
New Products 42
Meetings 56
Newscripts 78

Business

Productivity of the U.S. chemical industry continued to improve in 1987, but the rate of increase was slower than in 1986. **Page 11**

Government

Congress is considering legislation on a variety of topics of scientific interest including clean air amendments, pesticide registration. **Page 14**

Space station, defense research. NIH grants are among the programs federal budgeters would consider cutting to reduce deficit. **Page 16**

Science

Method for asymmetric dihydroxylation of olefins installs asymmetric configurations at two carbon atoms at once. **Page 19**

Polyacrylamide gel electrophoresis is adapted to capillary format by chemists at Northeastern University. **Page 20**

Technology

Aluminophosphate-based molecular sieves with pores greater than 10 Å show potential as cracking catalysts for petroleum refining. **Page 22**

Books

"Emergency Response to Chemical Accidents: Planning and Coordinating Solutions" by James T. O'Reilly is a useful primer for those new to coordinating emergency response plans. **Page 53**

Product Report

Outlook for rubber is moderately optimistic, with global consumption growing about 2% annually over the next five years to nearly 16 million metric tons in 1992. **Page 25**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago. Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 77)

LETTERS

Chemistry in the future

SIR: As I write, I am looking both at my 1987-88 dues and Paul G. Gassman's article, "Will chemistry exist in the future?" (C&EN, Dec. 14, 1987, page 51). Perhaps his question and what I feel I do not get for my dues are facets of a more serious deep-seated problem that has not yet been appropriately and directly articulated.

Let me answer his question. "Chemistry" certainly will exist in the future. The fundamental realities defined by that word, whatever they are, always have and always will exist. In another sense, chemistry, as we know it, is fated to disappear just as the chemistry of Lavoisier and Arrhenius, as they knew it, disappeared. I am not particularly troubled by his concern that there is a decline in the quantity and quality of U.S. students choosing Chemistry (note the capital) as a career. The former is a matter of fashion and government funding; the latter is truly debatable. Perhaps of more concern is what kind of education those who choose Chemistry are receiving.

The question that I really believe he is asking is, "Will ACS exist in the future?" I, of course, do not know the answer to that question, but I can express a hope. And that hope is that it does not do so in its present form or with its present priorities—whatever they really may be. Despite president Nelson's sanguine view, ACS has not been effective in representing chemistry or chemists either in the public eye or in the marketplace. That is not my judgment alone; the bill of particulars is to be found in Gassman's article, and in the passive ways ACS reports layoffs, in the rising tide of complaints arising in C&EN, and in the poor participation in local affairs.

I do not pretend to have the right answers and what suggestions I might make would make this letter too long, but I believe the society would be well served by a vigorous open debate of its function and how it can best serve both chemistry and chemists. The membership may decide it cannot do both effectively. If so, that is something the membership should know. I, thus, believe that the best return I could receive this year for my dues would be for the ACS officers and staff to provide the forums, both in C&EN and at local, regional, and national meetings, for these views to be expressed.

George W. Latimer Jr.
Bryan, Tex.

Memoirs of Henry Gilman

SIR: At the request of the Royal Society of London I am writing the biographical memoir of Henry Gilman, who was a foreign member of the society. I would be most grateful to receive from those who were associated with him any information about him that they think may be relevant for the memoir, including personal anecdotes that throw light on his character and style of working. Material relating to the period before about 1945 would be especially helpful.

Colin Eaborn
MOLS, University of Sussex
Brighton BN1 9QJ, England

The Bhopal crisis

SIR: Wil Lepkowski's uncritical review of "Bhopal: Anatomy of a Crisis" (C&EN, Jan. 11, page 24) cannot be allowed to pass without comment. His generally positive verdict manages to miss the major faults in the book.

The worst of these relates to definitions and is apparent right from the beginning. What is a crisis and why is it important? How would knowledge of the "anatomy of a crisis" be put to constructive use in industrial or public safety considerations? The author does not say. Nowhere in the book is "crisis" defined clearly or the benefits of understanding it explained.

The consequences of this become evident in Chapter 6 where Shrivastava states, "and even if deaths and injuries were inevitable, Bhopal would not have become a worldwide crisis if the different parties had worked together to alleviate aftereffects." What on earth is this? Has the avoidance of something called a "crisis" now become a priority? People may die, but at all costs we must avoid "crises." The implications are offensive.

The book has a number of other faults including the author's inability to avoid using emotive language. The accident was without doubt enough to appall anyone, but isn't this the best reason for some clear-headed analysis to find out exactly what happened and determine ways of avoiding similar events in the future?

Keith Weaver
Toronto, Ontario, Canada

Don't jargon it

SIR: In the interest of keeping life as simple as possible, and since we spend almost all our time communicating with people who speak our own language, it is important to minimize professional

Chemical Productivity Continues To Increase, But More Slowly

William J. Storck, C&EN New York

Productivity in the U.S. chemical industry continued to improve in 1987, but the rate of growth slowed from the year before. And toward the end of the year, productivity advances all but halted.

Using data published by the federal government, C&EN estimates that productivity for the chemicals and allied products industry rose 3.9% from 1986. Productivity is output per workhour, calculated by dividing the index for production by the index for workhours of production employees. The increase in 1987 is far below the 5.5% increase in 1986 and is the lowest growth rate for the chemical industry since 1982, when the recession-plagued industry's productivity fell 1.5%.

During the early 1980s, the chemical industry worked to trim employee rolls and to introduce production efficiencies into its plants. These steps, combined with natural productivity increases seen during recovery from recession, worked to provide large productivity increases. However, as the U.S. economy enters its sixth year of recovery, there are signs that productivity improvements from a trimmer work force have run their course.

These trends are reinforced by unit labor cost data, which also showed signs of declining improvement in 1987. Unit labor costs are labor costs per unit of output, calculated by dividing the index for wages by the productivity index. Labor costs (which would decline to show improvement) fell just 0.5% in 1987 from 1986. This compares

Productivity growth slowed for chemicals in 1987. . .

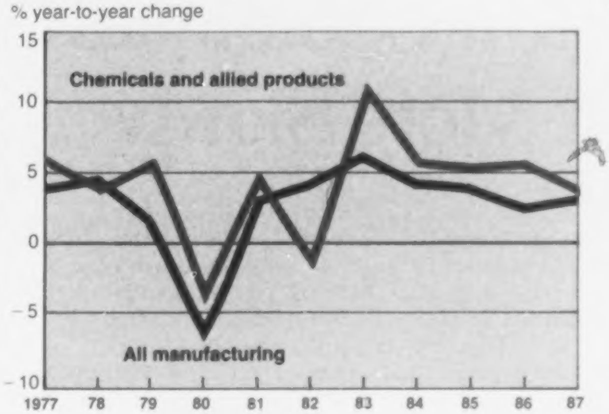
Indexes, 1977 = 100	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
CHEMICALS AND ALLIED PRODUCTS											
Production	140.0	133.0	127.1	121.6	113.9	103.8	112.6	106.4	113.3	106.3	100.0
Workhours	94.8	93.5	94.3	95.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0
Productivity	147.7	142.2	134.8	128.0	121.3	109.0	110.7	105.4	109.9	104.0	100.0
Hourly production wages	192.4	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2	109.2	100.0
Unit labor costs	130.3	130.9	133.7	135.0	135.9	142.2	128.2	122.6	107.6	105.0	100.0
ALL MANUFACTURING											
Production	134.6	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7	106.1	100.0
Workhours	93.6	93.0	93.3	94.8	88.2	87.0	97.9	98.9	106.4	104.5	100.0
Productivity	143.8	138.8	135.5	130.1	124.8	117.5	112.9	109.4	104.2	101.5	100.0
Hourly production wages	174.4	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0
Unit labor costs	121.6	123.3	123.2	124.1	124.4	127.3	124.7	121.5	113.2	107.0	100.0

. . .and fell in final two quarters of the year

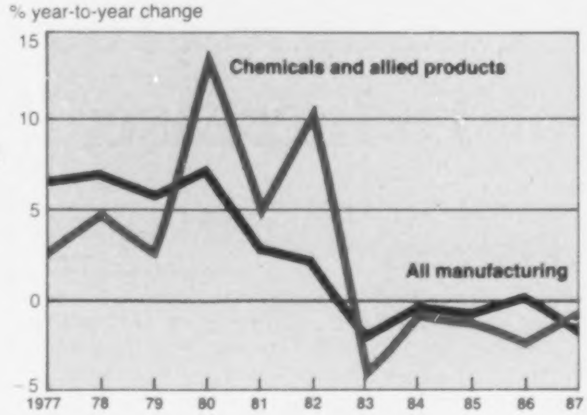
	Quarters, 1987				Quarters, 1986				Quarters, 1985		
Indexes, 1977 = 100	4th	3rd	2nd	1st	4th	3rd	2nd	1st	4th	3rd	2nd
CHEMICALS AND ALLIED PRODUCTS											
Production	144.2	141.8	138.2	135.8	133.6	134.1	132.8	131.3	127.9	128.1	126.8
Workhours	97.1	95.5	93.3	93.2	94.2	93.4	93.1	93.4	93.8	93.9	94.5
Productivity	148.5	148.6	148.2	145.7	141.9	143.6	142.7	140.6	136.3	136.4	134.1
Hourly production wages	195.5	193.2	191.2	189.8	188.8	186.9	184.8	184.1	183.9	180.7	178.6
Unit labor costs	131.7	130.0	129.0	130.3	133.1	130.2	129.5	130.9	134.9	132.5	133.1
ALL MANUFACTURING											
Production	137.9	135.7	133.2	131.6	130.4	129.4	128.4	128.4	127.4	126.8	126.2
Workhours	95.3	93.5	92.8	92.8	93.1	92.6	92.8	93.6	93.5	92.9	93.0
Productivity	144.7	145.2	143.6	141.8	140.1	139.7	138.3	137.3	136.3	136.5	135.6
Hourly production wages	176.3	174.5	173.7	173.2	172.1	171.0	170.8	170.5	169.4	167.8	167.0
Unit labor costs	121.8	120.2	121.0	122.2	122.9	122.4	123.5	124.2	124.3	122.9	123.2

Sources: Federal Reserve Board, Department of Labor, C&EN estimates

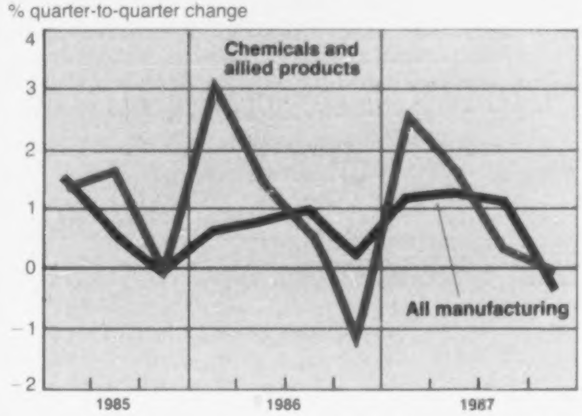
Annual productivity growth is still better for chemicals . . .



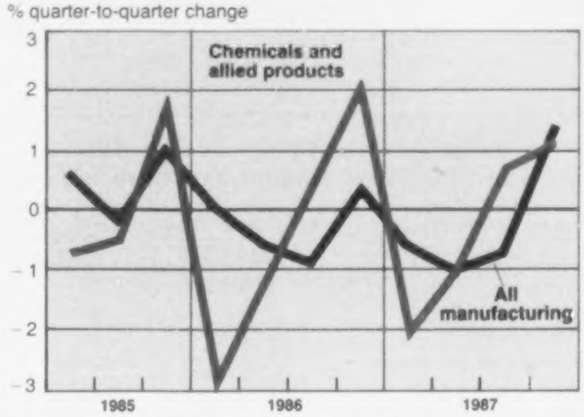
. . . but unit labor costs fell more for manufacturing in 1987



Quarterly growth has slowed considerably for chemical productivity . . .



. . . and unit labor costs began to escalate at the end of 1987



Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates

with a drop of 2.1% in 1986 and is again the poorest showing since 1982.

In spite of slowing improvement, the chemical industry outperformed the all-manufacturing category in productivity, but lagged in unit labor cost improvement last year. C&EN calculates that productivity for all manufacturing improved 3.6% in 1987 following a slow 2.4% improvement in 1986. Unit labor costs for all manufacturing declined a much better 1.4% in 1987, after remaining essentially unchanged in 1986.

Further signs that chemical industry productivity increases may be slowing came in the final two quarters of 1987, in which seasonally adjusted quarter-to-quarter data show a flattening of productivity and actual increases in unit labor costs.

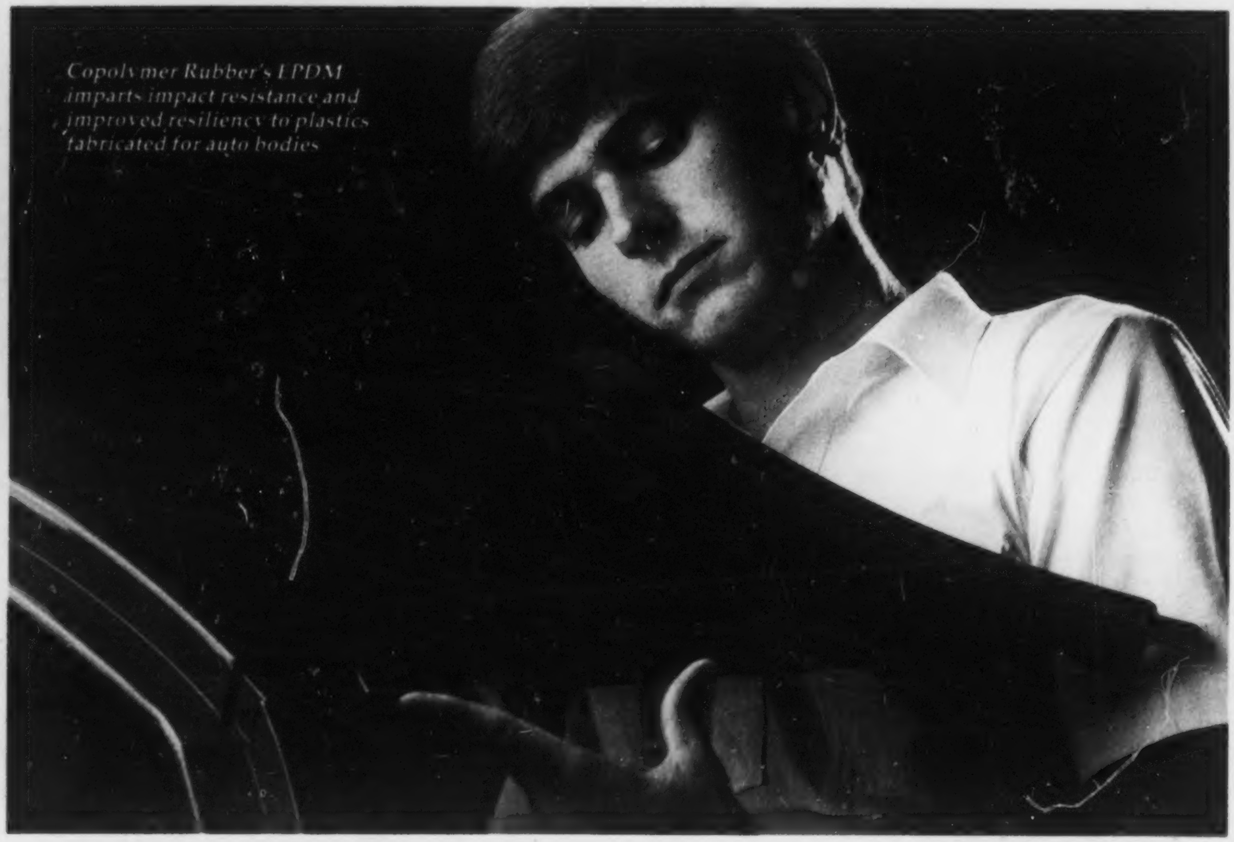
In the fourth quarter, productivity for the chemical industry was unchanged from the third quarter, which itself was up only 0.3% from the preceding three months. And unit labor costs in the fourth quarter actually increased, rising 1.3% from the third quarter, which had been up 0.8% from the second quarter.

For all manufacturing, fourth-quarter productivity declined 0.3% following a 1.1% improvement in the third quarter. Unit labor costs for all manufacturing increased 1.3% in the fourth quarter, slightly faster than for the chemicals and allied products sector, following a 0.7% decline in the previous period.

Even on a year-to-year basis, the quarterly data are showing mixed signals. For the fourth quarter, year-to-year productivity in the chemical industry increased 4.7%, following a 3.5% increase in the third quarter. But unit labor costs in the fourth quarter shot up, rising 3.0% from fourth-quarter 1986, following a decline of 0.2% in the third quarter.

For all manufacturing, productivity in the fourth quarter increased 3.3% on an annual basis, following an improvement of 3.9% in the third quarter. Unit labor costs declined 0.9% in the fourth quarter on an annual basis, following a decline in the third quarter of 1.8%.

Two quarters' data are not enough to show that productivity improvement has ceased for the chemical industry, but as the industry enters its traditionally strongest quarters of the year, the trend bears watching. □



Copolymer Rubber's EPDM imparts impact resistance and improved resiliency to plastics fabricated for auto bodies

Modest Growth Ahead for Rubber

Bruce F. Greek, C&EN Houston

For the past 10 years, the rubber industry has had little to cheer about. Now, although no cause for wild celebration, there may be reason to expect business to be slightly better.

The five-year forecast for worldwide rubber consumption calls for growth averaging 2% annually, according to the International Institute of Synthetic Rubber Producers (IISRP). That follows an upbeat year in 1987, when worldwide consumption apparently grew even more than 2%. However, while moving ahead, this mature industry will have few spectacular developments in demand for its products through the early 1990s.

According to IISRP's forecast, production of both synthetic and natural rubbers will grow in line with demand; no significant inventory building is expected. Synthetic rubber capacity also will grow moderately, and most capacity additions in North America will be for smaller-volume and specialty rubbers.

By 1992, worldwide consumption of synthetic and natural rubber will be 15.9 million metric tons, according to William E. Tessmer, IISRP's managing director. That will be an 11% rise from the 14.4 million metric tons estimated for 1987. Last year's consumption is estimated to have risen 3.3% over 1986's 13.9 million metric tons. About 68% of all new rubber consumed worldwide last year was synthetic.

Data on consumption and production of rubber are compiled by IISRP, an association of 51 synthetic rubber producers located in noncommunist countries. Its member companies provide more than 95% of the world's synthetic rubber produced in noncommunist nations.

According to IISRP, 1987 global consumption of synthetic rubber, including communist countries, increased 3.1% from 1986 to 9.75 million metric tons. In the U.S. and Canada, combined consumption increased 3.3% to 2.52 million metric tons last year, reversing the trend of recent annual declines. Synthetic rubber demand is forecast to continue growing in these two countries—but only modestly—for a 1.5% increase over the next five years to 2.56 million metric tons in 1992.

In other parts of the world, consumption is expected to grow much faster. In Latin America, for instance, synthetic rubber demand, although growing from a smaller base of 541,000 metric tons, is forecast to grow almost 20% in the five-year period to 648,000 metric tons. In the Asia/Oceania region, excluding communist countries, consumption is forecast to grow 16% overall to 1.74 million tons by 1992. Combined use in Western Europe, Africa, and the Middle East is expected to increase about 7.5% during the same period to 2.12 million metric tons.

IISRP forecasts that total rubber consumption in all communist countries will increase 16% during the next five years, reaching nearly 4.7 million metric tons in 1992, with 20% of that natural rubber. China and other Asian communist countries, including North Korea and Vietnam, will remain the only area of the world where more natural rubber than synthetic rubber is consumed. In those countries, however, synthetic rubber consumption is increasing faster than that of natural rubber, so synthetic's share will grow to 41% in 1992 from 40% in 1987 and 39% in 1986. In Eastern Europe, including the U.S.S.R., synthetic rubber consumption accounted for 88% of the 3.3 million metric-ton total last year. By 1992, that share will increase to about 90% as synthetic rubber use rises from 2.9 million metric tons to 3.3 million metric tons.

In noncommunist countries, natural rubber consumption is forecast to grow 9.5% overall in the five-year period. In Canada and the U.S., combined consumption is expected to remain essentially unchanged, but combined use in Western Europe, Africa, and the Middle East will increase about 7% to 1.16 million metric tons. Asia/Oceania's share of noncommunist countries' total natural rubber consumption also will increase, from 42% last year to almost 44% in 1992, representing a 15% increase over the period to 1.8 million metric tons. Latin America will have the fastest growth of any geographic area in demand for natural rubber, at 20%, with consumption there rising to 296,000 metric tons.

In noncommunist countries last year, synthetic rubber accounted for 63.4% of total new rubber consumption, according to IISRP. That share will remain fairly steady, declining only slightly to 63.1% by 1992. By then, natural rubber consumption will exceed 4 million metric tons and synthetic rubber will exceed 7 million metric tons.

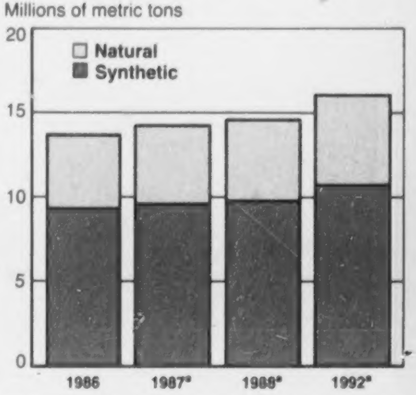
Styrene-butadiene rubber (SBR) will continue to be the largest-volume synthetic rubber produced and used in noncommunist countries. Consumption of both solid and latex forms totaled 2.58 million metric tons in 1986 and rose to 2.63 million metric tons in 1987, according to IISRP. Consumption is forecast to reach 2.66 million metric tons in 1988, and 2.82 million metric tons in 1992. Spurred by growing use in paper coatings, demand for another form—carboxylated SBR latex—is predicted to rise from 890,000 metric tons in 1986 to 1.02 million metric tons in 1992.

Among the other synthetic rubbers, polybutadiene ranks second to SBR in volume used. Total consumption in noncommunist countries in 1986 was just under 1 million metric tons and grew 6% last year to 1.06 million metric tons and is forecast to increase 7.7% over the next five years to reach 1.14 million metric tons in 1992.

The various ethylene-propylene rubbers are third in volume at 465,000 metric tons consumed in noncommunist countries in 1986. Consumption rose to 494,000 metric tons last year and is forecast to rise to 501,000 metric tons this year and to 556,000 metric tons in 1992, representing a five-year growth of 13%.

For smaller-volume synthetic rubbers, IISRP forecasts that polychloroprene consumption will grow to 268,000 metric tons in 1992 from 258,000 metric tons in 1987. Nitrile rubbers, in both the solid and latex forms, will increase 10% in the 1987–92 period, rising to 238,000 metric tons in 1992 from 216,000

Worldwide demand for natural and synthetic rubber rises



a Estimated. **Source:** International Institute of Synthetic Rubber Producers

Modest increases forecast for rubber consumption

Thousands of metric tons	U.S. & Canada		Western Europe		Latin America		Asia & Oceania		Africa & Middle East		Total	
	1987	1992	1987	1992	1987	1992	1987	1992	1987	1992	1987	1992
Styrene-butadiene[a]	839	833	727	745	329	386	674	783	63	72	**2,632**	**2,819**
Carboxylated styrene-butadiene	447	458	335	370	21	29	125	152	5	6	**933**	**1,015**
Polybutadiene	422	424	240	257	109	131	270	309	19	21	**1,060**	**1,142**
Ethylene-propylene diene	204	216	170	195	11	16	107	126	2	3	**494**	**556**
Polychloroprene	86	85	81	77	19	23	68	78	5	5	**259**	**268**
Nitrile	68	66	81	85	13	17	51	66	3	4	**216**	**238**
Other synthetics[b]	457	479	216	244	39	46	197	223	22	33	**931**	**1,025**
TOTAL SYNTHETIC	**2523**	**2561**	**1850**	**1973**	**541**	**648**	**1492**	**1737**	**119**	**144**	**6,525**	**7,063**
Natural	872	871	945	980	247	296	1568	1804	140	180	**3,771**	**4,131**
TOTAL RUBBER	**3395**	**3432**	**2460**	**2953**	**788**	**944**	**3060**	**3541**	**259**	**324**	**10,296**	**11,194**

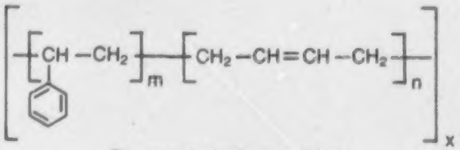
Note: Excludes communist countries. **a** Solid and latex forms of SBR. **b** Includes polyisoprene and butyl. **Source:** International Institute of Synthetic Rubber Producers metric tons in 1987. Consumption of all other synthetic rubbers (including butyl and polyisoprene rubbers), as well as the many specialty rubbers, is forecast to grow to 1.03 million metric tons in 1992 from 931,000 metric tons in 1987.

As has been the case for many years, tires continue to dominate rubber use. About half of all rubber consumption goes into making tires. In noncommunist countries, on a weighted-average basis, IISRP says, tires and tire products consume 43% of all synthetic rubber and 62% of natural rubber. In the U.S. and Canada, tires and tire products account for 43% of synthetic rubber consumption, and 72% of natural rubber consumption. In Western Europe, 35% of synthetic rubber consumption goes into tires, along with 66% of natural rubber. In Latin America, tires and tire products take the largest shares of rubber consumption among areas of the world, at 62% of synthetic and 77% of natural.

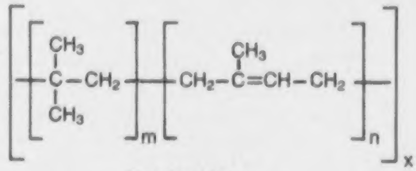
In the U.S., synthetic rubber production has grown to meet domestic and expanding export demands. Total synthetic rubber production last year increased 8.5% over 1986 to 2.18 million metric tons, according to the Rubber Manufacturers Association (RMA). Output in 1986 was up 7.4% from 1985. The 1987 level was the highest U.S. synthetic rubber production of this decade, surpassing the 1984 level of slightly less than 2.16 million metric tons. The all-time high in U.S. synthetic rubber production was in 1973 when more than 2.6 million metric tons were produced.

Imports of natural rubber into the U.S. account for most of the remaining rubber supply. Last year, they totaled 811,000 metric tons, up 5.4% from 1986 following a 9.4% drop from 1985.

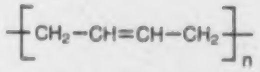
Structures of major elastomers



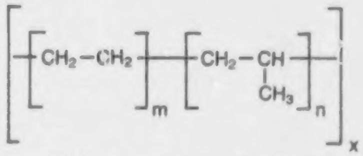
Styrene-butadiene rubber



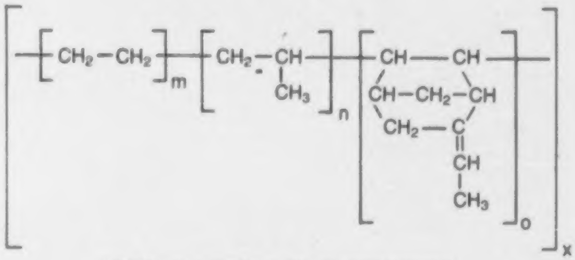
Butyl rubber



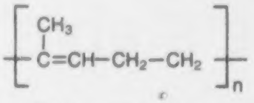
Polybutadiene rubber



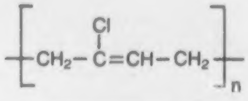
Ethylene-propylene copolymer



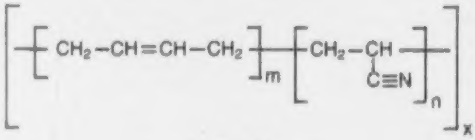
Ethylene-propylene-diene terpolymer[a]



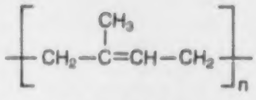
Polyisoprene rubber



Polychloroprene rubber



Nitrile rubber



Natural rubber

[a] Third monomer shown is dicyclopentadiene; ethylidene norbornene and 1,4-hexadiene are also used.

Both exports from the U.S. and imports to the U.S. of synthetic rubber are rising, but exports are up more than two and a half times as much as imports. Last year, exports totaled 454,000 metric tons, an increase of 28% over 1986. Imports of synthetic rubber rose 11% to 283,000 metric tons, according to RMA. Subtracting last year's imports from exports puts net exports at more than 171,000 metric tons, accounting for nearly all of the increased output of synthetic rubber in the U.S. last year.

Much of last year's growth in synthetic rubber output was accounted for by SBR, production of which rose 7.4% to more than 850,000 metric tons. That was up from 792,000 metric tons in 1986. Nevertheless, SBR production remains well below the historic high of more than 1.5 million metric tons set in 1973. Exports of SBR, however, rose to 172,000 metric tons, up more than 54% from 1986. Imports, meantime, fell 14% to 83,000 metric tons. The increase in net SBR exports to 89,000 metric tons from 16,000 metric tons in 1986 exceeded the increase in production by some 30,000 metric tons, suggesting a drawdown of inventories.

Production of polybutadiene rose about 10% in 1987 from the previous year to 371,000 metric tons. Imports increased 21,500 metric tons to nearly 82,000 metric tons, and exports climbed 37,000 metric tons to 61,000 metric tons. The decline in net imports over exports was 15,500 metric tons, a drop that accounted for nearly 45% of output growth for polybutadiene last year.

Among other synthetic rubbers, production of ethylene-propylene rubbers rose almost 11% in 1987 to more than 254,000 metric tons. Both exports and imports of these elastomers were up slightly during 1987, suggesting that most of the increased output was consumed in the U.S.

Production of all other synthetic rubbers grew at rates of 5 to 10% in 1987. Exports and imports of some of these rubbers had different patterns, with some showing declines in exports and some in imports.

For most synthetic rubbers produced in the U.S., the increase in exports accounts for a large part of the recovery in output during 1987. Growth of exports is partially a result of the declining value of the dollar. Improvement in product quality and plant efficiency by producers also is helping to spur exports.

Increased imports of tires and automobiles, combined with economic recessions, could cause U.S. consumption of these elastomers to remain below the levels of the 1970s. It's likely that growth in U.S. consumption will remain slow, with reverses during recessions likely to occur. Besides competition from imported fabricated rubber products, relatively few new products made of elastomers are coming to market. Product development in elastomers does continue, however, particularly in the area of solution polymers, which allows a polymer to be more closely tailored to a definite use than has been possible with emulsion polymers.

Some synthetic elastomers have always been made as solution polymers. Others, particularly SBR, have been adapted to solution polymerization. That process accounts for a growing share of production, although no breakdown is available on the fraction of SBR that is made using solution processes. A likely guess is that solution SBR accounts for less than 15% of total production in the U.S.

Developments such as solution polymerization of SBR to give elastomers more desirable properties for certain applications have helped keep SBR the largest-volume synthetic elastomer produced in noncommunist countries. SBR accounted for about half of that total of 5.3 million metric tons in 1986, the latest year for which data are available from IISRP.

Despite growth in use of solution SBR, emulsion SBR keeps its wide acceptance as an important rubber for making tires. Moreover, most of the emulsion SBR plants have long been paid for, except for the low costs of debottlenecking and process improvements. The two major ingredients of SBR are widely produced at low cost. Butadiene, for example, is now almost entirely recovered from coproduct streams in making ethylene. Styrene is produced by the simple alkylation of ethylene and benzene and by subsequent dehydrogenation. Benzene is widely available as an aromatic that also is coproduced with ethylene, or is made at relatively low cost during hydrocarbon reforming in petroleum refineries and then is purified.

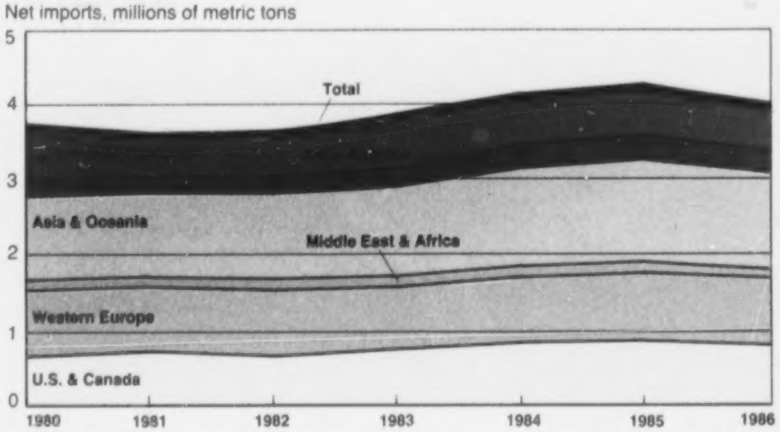
Processing simplicity of emulsion SBR continues to be an important factor helping to keep this rubber ahead of other synthetics. SBR long has been known to mix well with carbon black and other compounding materials, to form a continuous band in milling and then to extrude smoothly. The exact chemical reasons for such processing characteristics still aren't precisely known. Most rubber chemists, however, agree that the styrene configuration could be a major factor in ease of processing.

Emulsion SBR, as its process name implies, requires an emulsifying agent to stabilize an emulsion of the two hydrocarbon monomers in water, along with a variety of other chemicals such as initiators and modifiers. A common soap, such as sodium stearate, is most often used, although many kinds of soaps can go into making the various types. The soap and much of the other materials added to the emulsion are part of the finished SBR. The soap content can reach 5% or more, and the nonrubber materials in emulsion SBR may exceed 10% of the rubber weight. (This is in contrast to solution SBR, which seldom has more than 2% nonrubber materials in its finished form.)

In making emulsion SBR, the ingredients are fed continuously to a series of reactors whose temperatures are maintained at either about 5 °C or about 50 °C. The two temperatures distinguish between "cold" and "hot" emulsion SBR, and the two kinds have significantly different properties. In the last reactor, a short-stop is added to end polymerization. Unreacted butadiene then is flashed off and the unreacted styrene stripped. Afterwards, both monomers are purified and recycled. SBR is recovered from the latex in a process that may include an addition of antioxidants, extender oils, carbon black, and other chemicals, and that involves coagulation, dewatering, drying, and packaging.

Worker inspects baled raw butyl rubber at Polysar's Sarnia plant

Demand for natural rubber slipped in 1986



Note: Natural rubber produced and consumed within a region is included as an import. [a] Albania, Bulgaria, China, Czechoslovakia, East Germany, Hungary, North Korea, Poland, Romania, U.S.S.R., Vietnam, and Yugoslavia.
Source: International Rubber Study Group, London

The "hot" emulsion SBR process was developed first. It generally is allowed to run to higher conversions of the monomers, to give more branching in the polymer chain, and to give more incipient gelation. "Cold" emulsion SBR is stopped at a lower conversion and gives an elastomer that has better abrasion resistance. In tires, this property provides better treadwear. Elastomers of cold SBR also have better dynamic properties than do elastomers of hot SBR. Cold SBR elastomers generally have higher molecular weights, which allows more oil extension. All of these property differences combined have led to the replacement of most hot SBR by cold SBR in tire manufacture.

Solution SBR is made by copolymerizing styrene and butadiene in a hydrocarbon solvent (most often hexane or cyclohexane). The process usually is catalyzed (or, in the industry's terminology, "initiated") by butyllithium. The reactors and other facilities can be used interchangeably to make polybutadiene rubber. Small variations in reaction conditions and use of various branching and terminating agents are used to control properties of the finished elastomer. When polymerization is halted, and before the solvent is removed, antioxidants, oils, and other components desired in the elastomer are added.

Wineries use Goodyear's Plicord hose to transport juices of their grapes

By controlling process conditions, composition of ingredient mix, and additives, chemists can make solution SBR for tire treads with an optimum balance of wear resistance, traction, and rolling resistance. To do this, or to make an SBR for some other specific use, they control the ratio of styrene to butadiene, the distribution of styrene and butadiene units in the polymer, the ratio of vinyl, cis, and trans configurations in the butadiene units, the molecular weight and its distribution, and the amount and kind of branching. In making emulsion SBR, some of these properties, such as the ratio of styrene to butadiene, can be easily controlled. With current knowledge of the processes to make emulsion SBR, however, others are more difficult, or impossible, to control.

Besides reduction in tire sizes, the largest impact on consumption of SBR in tires has been the shift toward radial-ply passenger car tires, which tend to wear better and last longer. In building radial tires, greater stress is developed, which can cause the plies to separate in the uncured (green) tire. To overcome potential separation problems, tire builders want higher "green strength" in the rubber as it is compounded. Natural rubber provides more green strength than does SBR, resulting in the increased use of natural rubber in a radial tire at about 40% of the total rubber, in contrast with about 15% in the older, widely used bias-ply tire.

Use of SBR as a share of total rubber in larger size truck and bus tires always has been lower than in passenger car and light truck tires. At high tire loads, SBR has poorer dynamic properties that lead to heat buildup and shorter life and has lower abrasion resistance than do some other rubbers. Blends of polybutadiene rubber and natural rubber are more heavily used in truck tires to provide longer life.

Nontire uses of SBR take about 25% of consumption. A big share of these uses are in automotive applications (where SBR often is blended with other elastomers), such as hoses, belts, grommets, seals, and various extruded or molded items. Automotive, nontire consumption rises and falls with production of cars and trucks and with changes in physical property requirements of the parts, especially requirements involving service life and operating temperature.

Other nontire and nonautomotive uses of SBR range over most industries that require hoses, belts, gaskets, seals, and other extruded and molded products. SBR also goes into footwear, various kinds of solid wheels, roll covers, coated fabrics, and wire and cable insulation. A sizable quantity of SBR is sold as the latex to be applied as carpet backing. The outlook for growth in this diverse range of uses is about the same as in tires. It is modest,

Synthetic rubber is significant market for many monomers

Excluding specialty rubbers, synthetic rubbers are made from the same monomers used in making many other polymers. With the exception of butadiene, synthetic rubbers are not the largest use of any of these monomers. Synthetic rubber, however, does provide a substantial outlet for the monomers, and, in some cases, may be the major use for a plant's production.

Butadiene, styrene, ethylene, propylene, isobutylene, isoprene, acrylonitrile, chloroprene (2-chloro-1,3-butadiene), and a host of other organic chemicals become synthetic rubbers by way of numerous methods of polymerization. Because of losses during polymerization, the quantity of these monomers consumed annually in making synthetic rubbers can be estimated only roughly. For making the 2.1 million to 2.2 million metric tons of the major-volume synthetic rubbers last year, more than 2.5 million metric tons (5.5 billion lb) of the monomers would be required.

Butadiene, as the 1,3-isomer, is consumed in far larger quantities than any other monomer for synthetic rubber. In 1987, an estimated 850,000 metric tons of styrene-butadiene rubber and 365,000 metric tons of polybutadiene, plus additional quantities of other elastomers containing butadiene, were produced in the U.S. The other elastomers that require significant quantities of butadiene are polychloroprene and nitrile rubbers. More than 80% of U.S. butadiene consumption goes into elastomers of one kind or another; that's about 2.75 billion lb of the estimated U.S. consumption of 3.3 billion lb in 1987.

In 1987, prices of butadiene nearly tripled, rising from about 11.5 cents per lb in January to at least 32 cents per lb in October. (Prices were as low as 9 cents per lb in October 1986, down from 28 cents per lb in January of that year.) Since fall 1987, prices have weakened as supplies improved, dropping to 26 cents per lb in February of this year and rumored to go as low as 23 cents per lb this month.

Two factors affected butadiene supply in 1987. One was a temporary reduction early in the year of output from steam crackers, where butadiene is a coproduct of ethylene. The other was a reduction in imports of butadiene during 1986 and early 1987, as demand in Europe improved. Net imports of butadiene in 1986 were less than 275 million lb, down from more than 640 million lb in 1985. As a result, inventories of butadiene fell. Imports surged, however, during the second half of 1987, totaling 650 million lb through November. That surge contributed to increased inventories, and prices tumbled about 20%.

Both inventories and imports of butadiene are forecast this year to stay above 1987 levels. As a result, the temporary scrambling that some elastomer producers did in 1987 likely will not be repeated in 1988. If current prices are an indication of the level for the whole year, raw materials costs for elastomers containing butadiene could ease.

Styrene, consumed mainly in SBR, various styrene-butadiene latices, and thermoplastic elastomers, ranks next to butadiene as the largest-volume mono-

especially as long as large quantities of natural rubber are available at competitive cost and as long as other synthetic elastomers are available with better physical properties for certain uses.

In noncommunist countries, polybutadiene rubber is produced second in volume to SBR. Its polymerization processes are similar to those of SBR, although most polybutadiene rubber is made by the solution process. Either of the double bonds of butadiene can react during polymerization. The resulting polymer can contain a wide range of geometric isomerism. If both of the double bonds enter the reactions, a 1,4-addition results to give either the *cis*-1,4- or *trans*-1,4- configuration. If just one double bond reacts, a vinyl or 1,2- addition results with three possible configurations—isotactic, syndiotactic, and atactic. Depending on the kind of polymerization process used and the catalyst system, a wide range of compositions of polybutadiene configurations can be made.

Processing and fabrication of polybutadiene depends on polymer properties, but in general, this rubber processes with more difficulty than SBR. As a result, polybutadiene often is blended with SBR to improve milling and other characteristics. Improved wet skid resistance of tire treads and improved traction are two reasons for the blending of polybutadiene with SBR and natural rubber. The contributions of polybutadiene in tires include good resistance to wear and groove cracking, lowered rolling resistance, and low heat buildup.

As a result, tire uses of polybutadiene elastomers, which include all kinds of tires and retreading rubber, amount to about 80% of U.S. consumption. Most of the remaining use of polybutadiene is as an impact modifier for polystyrene and other resins by graft polymerization. Impact-modified polystyrenes include polybutadiene contents in the range of 2 to 10%. The remainder of polybutadiene elastomer consumption is in various extruded and molded industrial rubber products.

In terms of production, ethylene-propylene elastomers rank next in size to polybutadiene. The copolymers are produced in much lower volumes than are the terpolymers, with terpolymers accounting for about three quarters of U.S. output. The third type of monomer (known as dienes) in terpolymers of commercial significance is either dicyclopentadiene, ethylidene norbornene, or 1,4-hexadiene. Each of these termonomers produces different characteristics in the final elastomer. Dicyclopentadiene yields elastomers with the slowest cure rates of the dienes and gives a polymer with branched chains, as a result of its second double bond having low reactivity. Ethylidene norbornene, made by reacting butadiene with cyclopentadiene, may be the widest used of the termonomers because it is the most easily incorporated into the polymer. The double bond, so introduced, improves sulfur vulcanization. Both linear and branch-chain terpolymers with desired final properties can be made with ethylidene norbornene by varied polymerization conditions. Use of

CIRCLE 34 ON READER SERVICE CARD →

mer going into elastomers. In 1987, those uses likely totaled more than 800 million lb. However, SBR required only about 40% of the total going into elastomers, a little more than 10% of total production of about 7.9 billion lb.

Styrene supplies became tight worldwide during 1987. Elastomer producers in the U.S. and Canada who use styrene as a polymer component had less difficulty getting it than they did getting butadiene. Demand for styrene to make polymers and for export grew rapidly in 1987, and prices rose accordingly. Demand for styrene remains strong and prices are relatively firm around the world.

Production of styrene in the U.S. is expected to increase slightly through debottlenecking programs. The size of capacity additions likely will be small—less than 5% increases. And producers will continue to run their plants all out as they did in 1987.

Isobutylene, highly purified, is the primary monomer for the various butyl elastomers. The U.S. has only one producer, Exxon Chemical. Data on production of butyl elastomers are put in the "all other" category. As a result, no accurate estimate of isobutylene consumption in these elastomers is possible. Based on estimated demand growth for butyl elastomers on the latest available data, isobutylene use for elastomers may be around 300 million lb per year. That volume is but a small part of total isobutylene production from both refinery catalytic and steam cracking.

Ethylene and propylene, used in making ethylene-propylene and ethylene-propylene-diene elastomers, are produced in volumes of about 35 billion lb and 20 billion lb, respectively. The elastomers this year will require about 500 million to 600 million lb of the two olefins, a small part of total consumption. As a result, no supply difficulties will be experienced, although raw material costs will be up because of the nearly doubled prices for the olefins.

Isoprene, or 2-methyl-1,3-butadiene, production in 1986 was reported at just under 140 million lb by the U.S. International Trade Commission. Because isoprene for use in making polyisoprene elastomer and other elastomers is purified from C_5 streams from cracking, not all production may have been reported because of the low concentrations. Apparently, sufficient isoprene is recovered to meet demands from elastomer manufacture and will continue to be, since production of elastomers requiring it is growing slowly.

Acrylonitrile, used in nitrile elastomers as a copolymer with butadiene, is produced at a rate of about 2.5 billion lb per year. Nitrile elastomers will require about 50 million lb of acrylonitrile this year, making it likely that no supply problems will be encountered by its producers.

Chloroprene is made into neoprene elastomers—the production of which is no longer reported. The two U.S. producers, Du Pont and Mobay Synthetics, make their own monomer. Based on historical elastomer production data, monomer output probably totals about 250 million lb per year.

1,4-hexadiene as the third comonomer will give elastomers having good processing characteristics and heat resistance.

Most ethylene-propylene elastomers are made in a solvent such as hexane, using Ziegler-Natta catalyst systems for polymerization. After polymerization is stopped, the unreacted monomers are flashed off and recovered. If wanted, extender oils can be added before the solvent is removed and the polymer prepared for packaging.

A wide range of compositions is possible for the co- and terpolymers. Most commercial grades of copolymer elastomers have 40 to 60% ethylene in them. Commercial grades of terpolymers, often abbreviated EPDM, have about the same ratio of ethylene to propylene and up to about 10% of diene.

Curing, or vulcanization, of the ethylene-propylene elastomers varies, depending on whether a diene is present. The copolymers are considered to be saturated elastomers and therefore require a peroxide cure, although sometimes sulfur also is present. The terpolymers most often are cured with conventional sulfur-containing recipes. Cures are differentiated to fit the polymers, which, in turn, often are specifically made for the type of fabrication—extrusion, molding, or calendering—expected to be encountered.

The automotive market (excluding lubricating oil additives) is still the largest for ethylene-propylene elastomers, although some nonautomotive uses are growing faster now. Tire use is small, with most of the ethylene-propylene rubber going into the white strip on passenger car sidewalls. Automotive uses predominantly are in hoses, seals, grommets, and weather stripping. Additional quantities of this elastomer are blended with polyolefins to make thermoplastic olefin elastomers that go into bumper parts, some exterior body parts such as fender extensions and rub strips, wire and cable coverings, and numerous other items.

Nonautomotive uses of these elastomers cover a wide range. For a while, use in single-ply roofing increased rapidly. Now this application has slowed as capture of this market has reached high levels. Copolymers have had recent rapid growth as viscosity-index improvers in lubricating oils, particularly the multiviscosity-grade oils because of cost-performance characteristics. Other uses of ethylene-propylene elastomers include modifiers for thermoplastics (to give improved impact and stress crack resistance), wire and cable insulation (particularly for exterior applications), hoses of many kinds, appliance parts, and other extruded and molded products.

Polyisoprene, another widely used synthetic rubber, is made in a process similar to that for polybutadiene—an addition polymerization. Because of the 1,3-diene structure of isoprene, the reaction can involve the same three double bond positions as in butadiene and can yield the different configurations. Of the eight possible arrangements for polyisoprene, three have been isolated: the *cis*-1,4-, *trans*-1,4-, and atactic-3,4- forms. Polymerization is carried out in a hydrocarbon sol-

← CIRCLE 34 ON READER SERVICE CARD

vent using Ziegler-Natta catalyst systems. Depending on the makeup of the catalysts, a very high content of *cis*-1,4-polyisoprene can be made, although it is not so high as is found in natural rubber polymer, in which it may be more than 99%.

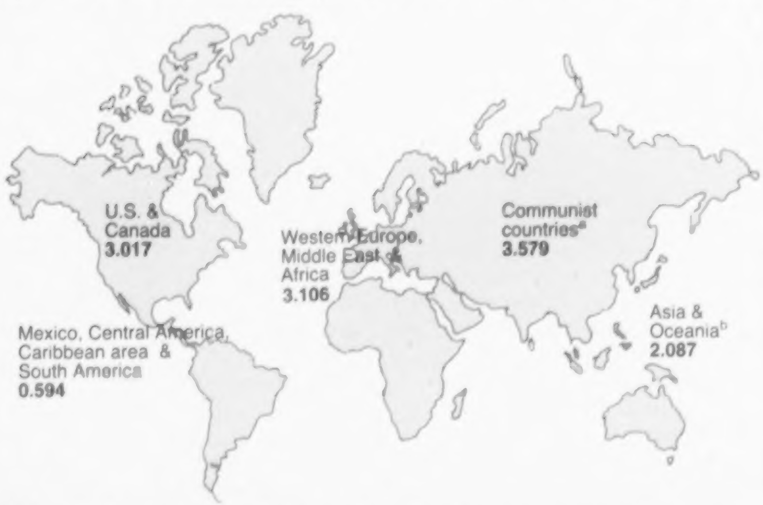
Because of its similarity to natural rubber, the *cis*-1,4- form of polyisoprene is used mostly in making tires. With additives, it will provide tires with about the same level of green strength as will natural rubber. Most polyisoprene used in passenger car and light truck tires goes into sidewalls because blends of polybutadiene rubber provide better properties for treads. More polyisoprene, as a share of total rubber content, goes into truck and bus tires where it is substituted for natural rubber in blends with polybutadiene to provide the properties of good resistance to heat buildup and good abrasion resistance in treads. Consumption of polyisoprene in tires likely will grow slowly, especially since radial tires have replaced most bias tires for passenger cars.

Nontire uses of polyisoprene elastomers account for about 40% of consumption. In many of those uses, the elastomers substitute for natural rubber, depending on the price of natural rubber. The fabricated forms of rubber products made of polyisoprenes are the same as those made of other rubbers. These products are mechanical goods, made by extrusion or molding, for automotive and other industries, footwear, and many other smaller-volume items. Nontire uses probably will grow 3 to 5% annually, as influenced by fashion in footwear, auto production, and developments in other fields such as medicine.

An interesting aspect of polyisoprene is that capacity for making the polymer in the U.S.S.R. is estimated by IISRP to be more than 1 million metric tons per year, several times the combined capacity in noncommunist countries. The reason for such large capacity in communist countries apparently is to minimize dependence on natural rubber, now slightly more than 20% of total new rubber consumption in those countries.

Butyl rubbers (including the halobutyl rubbers) also are important tire elastomers. Butyl use in tires is almost exclusively as the inner liner for tubeless tires and in tubes for tires, because of its very low air permeability compared to natural rubber or SBR. Butyl elastomers are copolymers of isobutylene and a small amount of isoprene. The commercial halobutyls are either chloro- or bromo- derivatives.

Synthetic rubber capacity tops 12 million metric tons


U.S. & Canada
3.017
Western Europe, Middle East & Africa
3.106
Communist countries[a]
3.579
Asia & Oceania[b]
2.087
Mexico, Central America, Caribbean area & South America
0.594

[a] Albania, Bulgaria, China, Czechoslovakia, East Germany, Hungary, North Korea, Poland, Romania, U.S.S.R., Vietnam, and Yugoslavia. [b] Afghanistan, Australia, Bangladesh, Burma, Cambodia, India, Indonesia, Japan, Laos, Malaysia, New Zealand, Pakistan, Philippines, South Korea, Sri Lanka, Taiwan, and Thailand.
Source: International Institute of Synthetic Rubber Producers

Butyl elastomers are made by polymerizing a solution of isobutylene and isoprene in methyl chloride, using aluminum chloride as the catalyst at about −100 °C. The reaction is fast and exothermic. During polymerization, a slurry forms of butyl elastomer and the solvent. The polymer-hydrocarbon solvent slurry is contacted with hot water in a flash drum where most of the unreacted monomers and solvent are removed overhead. An antioxidant and zinc stearate is added to the polymer to prevent breakdown and agglomeration. The polymer-water slurry then goes to a vacuum-stripper to remove residual hydrocarbons and then to a dewatering extruder. From there, it goes to a drier.

To make halogenated butyl elastomers, the elastomer is dissolved in a hydrocarbon solvent, usually hexane, and treated with chlorine or bromine in a high-intensity mixer. Coproduct halogenic acids are neutralized with dilute aqueous caustic solution. After neutralization, the caustic phase is separated from the mixture, the polymer-solvent stabilized, and an antioxidant added. The finishing steps are similar to those for nonhalogenated butyl elastomers.

Vulcanization of both kinds of butyl elastomers can involve a variety of techniques, ranging from use of a conventional sulfur crosslinking, through use of dioximes, to use of bis-alkylation with such compounds as primary diamines. The elastomer and its selected cure depends on the final end use and on the fabricated form of use. For example, a butyl rubber to be used for an exterior cable insulation requiring high ozone and weather resistance would be of a type that has low unsaturation in the polymer and a cure system containing *p*-quinone dioxime.

Besides ozone and weather resistance, butyl elastomers can be tailored to have good thermal stability (for elastomers), vibration damping characteristics, and chemical and moisture resistance. Tire components require the largest share of butyl elastomer consumption in the inner liners as well as in sidewalls. Some of the other uses are in seal-

U.S. tire production holds below decade-old peak . . .

Millions of units	Passenger car	Truck & Bus	Total
1977	193.4	38.2	**231.6**
1978	183.2	40.2	**223.4**
1979	168.0	38.7	**206.7**
1980	130.9	28.4	**159.3**
1981	149.8	32.0	**181.8**
1982	149.5	29.0	**178.5**
1983	156.3	30.7	**186.9**[a]
1984	172.9	36.4	**209.4**[a]
1985	162.6	33.3	**195.9**
1986	159.4	30.9	**190.3**
1987[b]	168.3	35.8	**204.1**

a 0.1 difference due to rounding; b C&EN estimate based on 10-months reported production.
Source: Rubber Manufacturers Association

. . . as tire imports climb to more than 20% of output

Millions of units	Passenger car	Truck & Bus	Total
1977	13.0	4.1	**17.1**
1978	12.9	4.3	**17.2**
1979	15.2	4.8	**20.0**
1980	13.7	4.3	**18.0**
1981	17.5	3.9	**21.4**
1982	16.9	3.7	**20.6**
1983	23.0	4.5	**27.5**
1984	30.1	6.6	**36.7**
1985	32.8	7.8	**40.6**
1986	34.0	7.6	**41.6**
1987[a]	38.9	8.8	**47.7**

a C&EN estimates based on 10-months reported imports. **Source:** U.S. Department of Commerce

ants and adhesives, hoses, gaskets, pads for truck cabs, bridge bearing mounts, and in other places where vibration damping is important. Growth in demand for butyl elastomers clearly depends on tire production, which probably takes 75% of consumption.

Polychloroprene elastomers are polymers of chloroprene, 2-chloro-1,3-butadiene, that are made by an emulsion polymerization using a rosin soap as the emulsifying agent and using an initiator of an alkali persulfate with sulfur present. Variations in the polymerization process lead to a large number of different elastomers (both solid and latex forms) designed for specific uses. Polychloroprenes generally are noted for their resistance to abrasion, hydrocarbons, sunlight, ozone, and weathering, and for their tough-

PRODUCT PROSPECTUS

Pyridine chemistry... cover to cover.

NEPERA
PYRIDINE AND DERIVATIVES

Brochure on pyridine and its derivatives includes technical data, specifications, and applications on these versatile chemicals:

- 4-DMAP
- Pyridine
- Piperidine
- 2-Cyanopyridine
- 3-Cyanopyridine
- Picolinic Acid
- Beta-Picoline

Get your free copy today.

NEPERA

Nepera, Inc.
Route 17
Harriman, NY 10926
(914) 782-8171

CIRCLE 16 ON READER SERVICE CARD

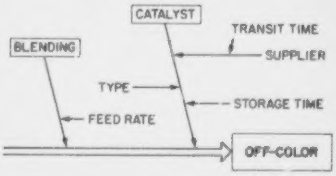
RENTAL
THE ALTERNATIVE

We make it easy to acquire analytical instruments

United States Analytical Instruments
A U.S. Leasing Company
1511 Industrial Rd
San Carlos, CA 94070
(415) 595-8200
800-437-9701 800-824-0060 (In CA)

CIRCLE 25 ON READER SERVICE CARD

NOW WHAT?



Quality improvement efforts often produce "fishbone" diagrams for potential causes (factors) of observed effects. You then need experimental information to decide which factors are the most important.

SCREEN™ software for the 256K IBM-PC/XT/AT generates and analyzes two-level Plackett-Burman experimental designs to screen up to 35 factors and up to eight effects. Foldover (reflection) of the design, duplication, and/or replication are available. SCREEN generates a separate worksheet for use with each experiment.

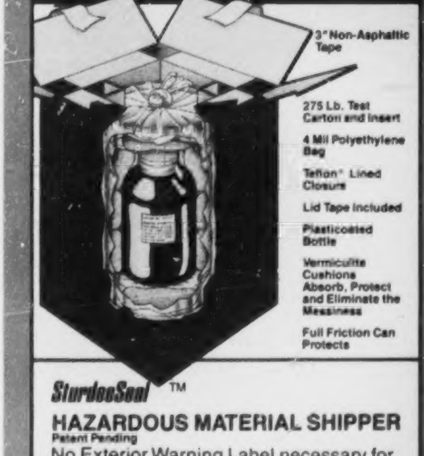
$295.00. Check or purchase order accepted. Outside USA: Write for details.

Statistical Programs
9941 Rowlett, Suite 6
Houston, TX 77075 USA
(713) 947-1551

IBM-PC is a registered trademark of International Business Machines Corporation.

CIRCLE 44 ON READER SERVICE CARD

SHIP HAZARDOUS MATERIALS VIA UPS, FEDERAL EXPRESS AND AIR CARGO


3" Non-Asphaltic Tape
275 Lb. Test Carton and Insert
4 Mil Polyethylene Bag
Teflon® Lined Closure
Lid Tape Included
Plasticoated Bottle
Vermiculite Cushions Absorb, Protect and Eliminate the Messiness
Full Friction Can Protects

SturdeeSeal™
HAZARDOUS MATERIAL SHIPPER
Patent Pending
No Exterior Warning Label necessary for domestic shipments. D.O.T. Exemption E-9168 permits UPS®, Federal Express®, United Nations International and U.S. air cargo shipping.

NO EXTERIOR WARNING LABEL

All-Pak

All-Pak, Inc. • 2260 Roswell Drive
Pittsburgh, PA 15205 • Phone: (412) 922-7525

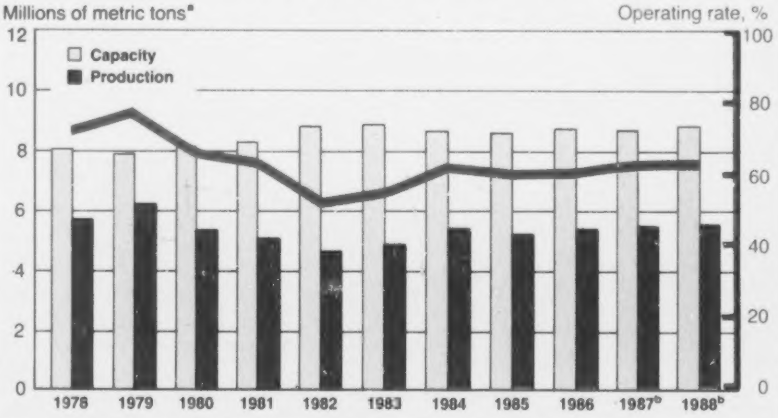
CIRCLE 1 ON READER SERVICE CARD

ness. They also are noted for being more difficult to compound than most synthetic elastomers.

Uses of polychloroprene elastomers range from adhesives to wire coverings. Other than small amounts in some tire sidewalls, polychloroprene elastomers are not used in tires. The largest use is in making mechanical rubber goods for automotive, petroleum production and transportation, construction, and consumer products. Those uses all take advantage of polychloroprene's properties. For example, in oil production and transportation, the elastomers are fabricated into well packers, other seals, gaskets, and hoses. Latices are used in making gloves, adhesives, and binders.

More than 200,000 metric tons of nitrile elastomers were produced in the noncommunist countries in 1987, a production level that has changed very slowly during recent years. In the U.S., the production of solid nitrile rubber by its four producers—Copolymer Rubber & Chemical, B. F. Goodrich, Goodyear Tire, and Uniroyal Chemical—totaled more than 68,000 metric tons and was the highest of this decade. The net of imports over exports of nitrile elastomers added about 4000 metric tons more to the supply.

Global capacity use for synthetic rubber has turned up



Note: Data include latices but exclude specialty rubbers. **a** Excludes communist countries. **b** C&EN estimate.
Source: International Institute of Synthetic Rubber Producers

Nitrile elastomers are copolymers of acrylonitrile and butadiene with properties varying, mainly depending on the composition of the polymers. Elastomers with high acrylonitrile content (40 to 50%) generally have higher resistance to hydrocar-

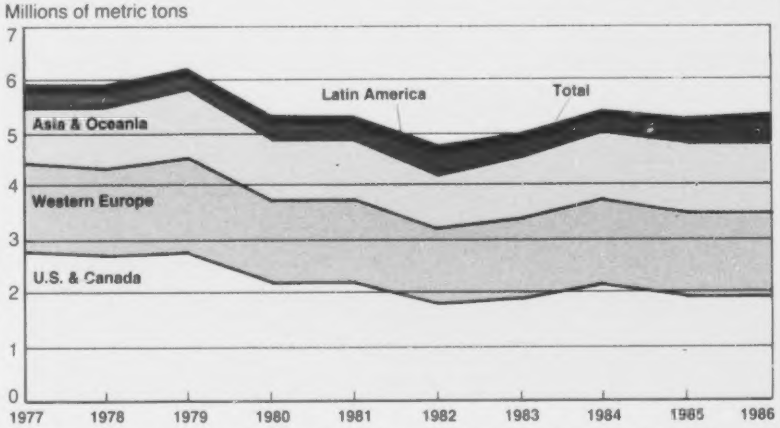
Everything.

*Trademark of The Dow Chemical Company

bons and abrasion and lower permeability to gases. Elastomers with low acrylonitrile content (about 20%) are more resilient and retain resilience at lower temperatures.

The polymerization processes for nitrile rubbers are similar to those used for emulsion SBR and are operated either as hot or cold and as batch or continuous processes. Soaps, catalysts, and other components of the recipe may be specifically different from those used in making SBR, but often they are chemically similar. Because nitrile elastomers are resistant to hydrocarbons, oil extension rarely is used in the polymer finishing process.

Production of synthetic rubber holds below peak levels

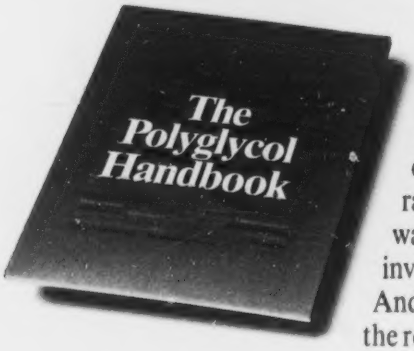


Note: Excludes communist countries. South African production is included with Asia & Oceania for 1977 to 1979, Latin America for 1980 to 1982, and Western Europe for 1983 to 1986.
Source: International Institute of Synthetic Rubber Producers

Because of their hydrocarbon-resistant property, nitrile rubbers mostly are used to handle oils, fuels, and chemicals, in the form of hoses, tubing, gaskets, seals, and packers. These fabricated items go into transportation equipment of all kinds, food processing, and crude petroleum production items. Various nitrile elastomers also are used to modify plastics such as polyvinyl chloride and acrylonitrile-butadiene-styrene to impart impact resistance. Uses of the latex form include paper saturation for masking tapes, building papers, and label stock. Competition is strong, however, so the outlook for growth in demand for nitrile elastomers is low.

Nitrile elastomers are sometimes put into the category of specialty elastomers, which can include the

From stop to bottom.



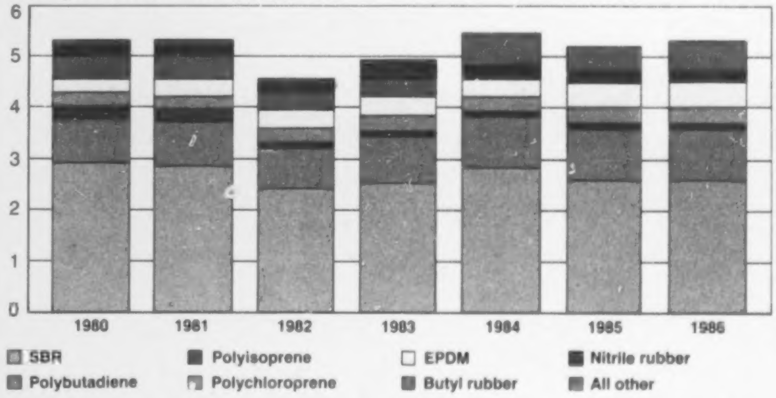
Dow polyglycols perform. As everything from lubricants in brake fluids to ingredient carriers in suppositories. And beyond. Dow's unique alkoxylation capabilities give you the freedom to create new applications with custom ethylene oxide, propylene oxide, and butylene oxide derivatives. For an almost unlimited range of product possibilities. And now, everything you've always wanted to know about polyglycols has been condensed into one invaluable technical resource. The Dow Polyglycol Handbook. And a copy is yours when you call 1-800-258-CHEM. Or circle the reader service number below.

DOW
Polyglycols
The possibilities are endless.

CIRCLE 8 ON READER SERVICE CARD

Other elastomers grow at expense of SBR

World production, millions of metric tons[a]



Note: Latex forms included in individual polymers totals; butyl rubber production is included in "all other" category for 1984 to 1986. **a** Excluding communist countries. **Source:** International Institute of Synthetic Rubber Producers

polyurethanes, silicones, fluorocarbons, thermoplastics, and others. Except for the the major-volume elastomers and nitrile, polyisoprene, and polychloroprene elastomers, production and use patterns for other elastomers are not available from industry groups. For this "all other" group, IISRP reports noncommunist countries' production at more than 500,000 metric tons in 1986. U.S. production in 1987 of all other elastomers, including polyisoprene, totaled 638,000 metric tons, up from 596,000 metric tons in 1986, according to RMA.

Among the specialty elastomers, the polyurethanes have become the most widely used, with estimates of total production at more than 200,000 metric tons per year. The diversity among producers, the forms, and the uses make definitive data impossible to obtain. These elastomers can be made by solution, suspension, and melt polymerization, all from a variety of monomers, into polymers that are fabricated by casting, molding by different methods, milling, and other means. The uses include tires (usually solid), gaskets, automotive body parts, many kinds of hoses and cable coverings, and consumer products as in seating.

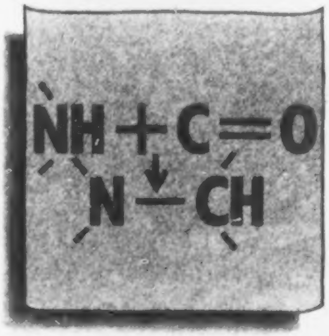
Silicone elastomers probably are second in size among the specialty elastomers after polyurethanes, excluding the nitriles. U.S. production is about 25,000 metric tons annually, but such a figure cannot be verified. Even though silicone elastomers have high prices, their use can be justified in applications demanding high resistance to heat, weather, and compression-set. Automotive mechanical goods and construction sealants are the major uses of these elastomers.

A large number of other specialty elastomers are made throughout the world. There is lack of agreement on whether some products are true elastomers, whether other products also should be included in this category, and whether products are produced in sufficient volume to be a commercial specialty elastomer. Some of the specialty elastomers have been commercially available for a long time. For example, polysulfide elastomers were offered more than 50 years ago. Some, such as thermoplastic elastomers, are produced in larger volumes than are some general-purpose elastomers, although data on thermoplastic elastomers output are elusive.

These specialty elastomers provide an extensive array of physical property, cost, and performance characteristics. Many are expensive, but because they meet demanding conditions of use, they are worth the cost. Uses include automotive items, aerospace equipment, medical devices, pollution control equipment, and a host of other industrial components.

The specialty elastomers, as a group, add little to the total volume of elastomer production, but they are profitable for producers. ☐

Reductive Amination.



Creative catalysis coupled with a multipurpose hydrogenation facility.

Being experts in catalysis and process research means we can help find the most efficient route to the new specialty amines you need.

What's more, our facilities include modern research labs, a pilot plant and one of North America's largest batch hydrogenation plants. An expert team of scientists and commercial development specialists is dedicated to seeing that every project is handled in the most economically and technically effective way.

From R&D through scale up and commercialization, we can take your product from start to finish. This can cut your workload, capital investment and ease the demand on your research and manufacturing resources.

For specialty amines, and for all your carbon-nitrogen-based chemical needs, call us at 800-345-3148.

©Air Products and Chemicals, Inc., 1988

More than chemicals. Chemistry.

AIR PRODUCTS

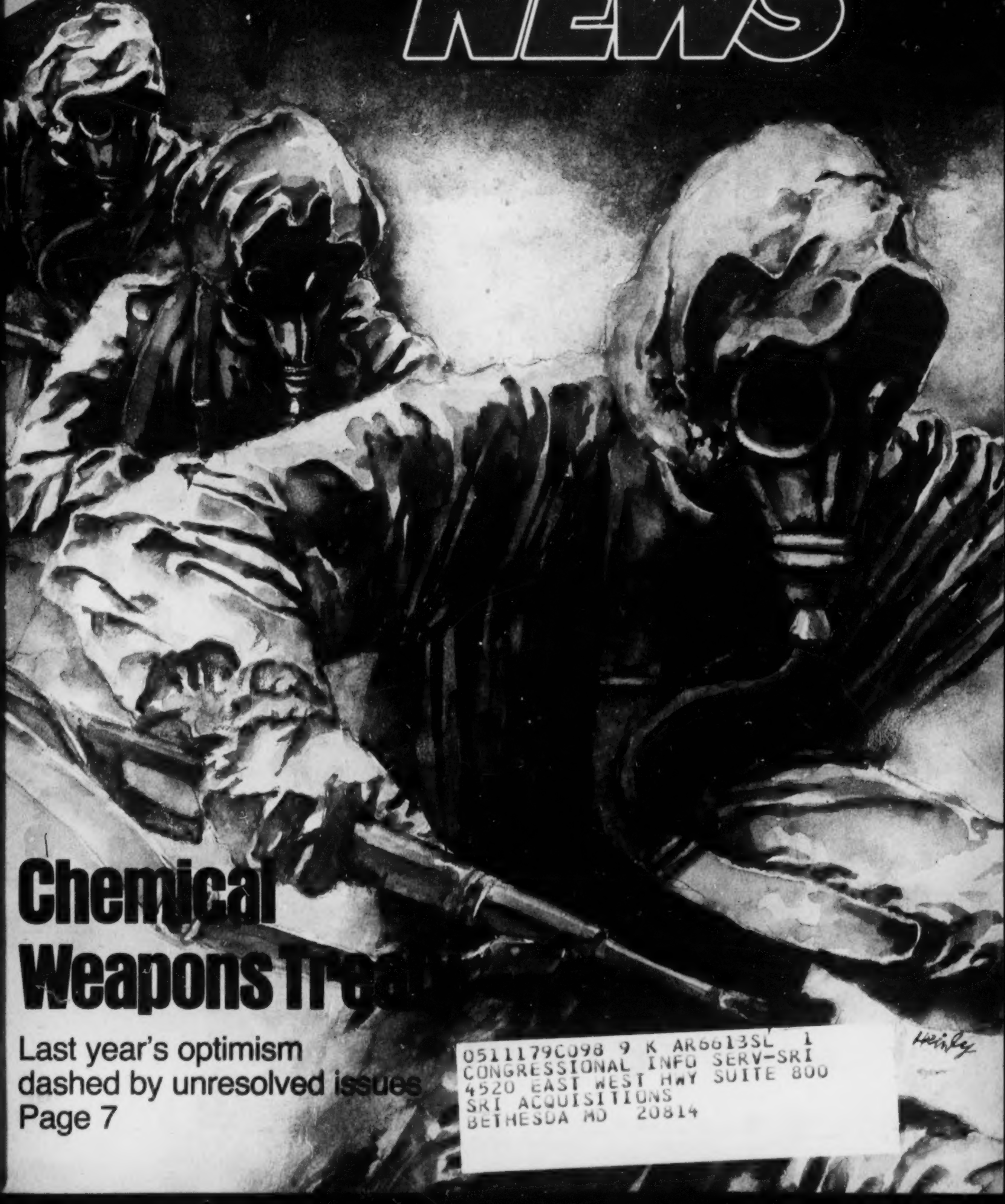
CIRCLE 33 ON READER SERVICE CARD

A1250-1

MARCH 28, 1988 3/31/88

CHEMICAL & ENGINEERING NEWS

FINAL PROGRAM
3rd Chemical Congress of
North America, Toronto Page 39



Chemical Weapons Trea

Last year's optimism
dashed by unresolved issues
Page 7

0511179C098 9 K AR6613SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 66, Number 13
CENEAR 66 (13) 1–164
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

MARCH 28, 1988

News of the Week

- **In the face of a likely reduction in fiscal year 1989 Superconducting Super Collider funding to a fraction of that requested, project backers are fighting for Congressional support.** **Page 4**
- **The Federal Trade Commission has ordered B. F. Goodrich to sell a vinyl chloride plant the company purchased from Diamond Shamrock five years ago.** **Page 5**
- **Scientists report no evidence of an increase in birth defects in children born in the Seveso, Italy, area following a 1976 dioxin accident.** **Page 5**
- **Shell and American Cyanamid will unite major parts of their catalyst businesses in a 50-50 joint venture called Criterion Catalyst Co.** **Page 6**
- **The House of Representatives has approved budget ceilings that could result in fiscal 1989 funding increases for NSF, NASA, and Department of Energy science programs.** **Page 6**

Letters 2
Editor's Page 3

Concentrates
Business 19
Government 23
Science/Technology 28

The Departments
Meetings 163
Newscripts 164

Business

Some biotechnology companies began to record profits in fourth-quarter 1987, as more products came to market. **Page 21**

DSM of the Netherlands, Finland's Kemira plan to exchange fertilizer operations, another move in the ongoing restructuring of Europe's troubled fertilizer industry. **Page 22**

Government

Concerns about pollution control are rising as efforts to amend the Clean Air Act are well under way and major metropolitan areas face August deadline to meet air quality standards. **Page 24**

A number of science and technology projects are on President Reagan's list of wasteful-spending items in the fiscal 1988 budget. **Page 26**

Science

AIDS research progresses quietly, advancing scientists' understanding of the disease, raising hopes for ways to treat it and prevent it. **Page 29**

ACS News

Science exhibit at Smithsonian Institution, scheduled to open in 1992, will be funded from society's fund-raising drive. **Page 34**

Final Program

Program for 3rd Chemical Congress of North America and 195th ACS National Meeting in Toronto includes listing of general events, technical papers, registration form. **Page 39**

News Focus

After nearly a decade of negotiations on a treaty that would ban development, production, and stockpiling of chemical weapons, diplomats at the Conference on Disarmament in Geneva anticipate continued slow but steady progress in the next couple of years. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager), Alan Kahan (Art Director), Barbara Fryer (Production/Art Director), Linda Mattingly (Staff Artist), Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600, TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 163)

LETTERS

CHEMICAL SAFETY

Explosive diazide compound

SIR: The purpose of this letter is to alert the chemical community to the unpredictable explosive properties of trans-1,2-cyclopropanedicarbonyl diazide. We have had the experience of preparing this compound several times (0.02 to 0.5 mole) without mishap. However, on the last occasion, 0.25 mole of the material detonated violently while at room temperature in toluene (100 to 150 mL) immediately after a Teflon-coated magnetic stirring bar was slid into the 1-L flask containing the solution. Personal injury resulted.

The literature procedure being followed (with the modification of using 150 mL instead of 400 mL of toluene) was that for *cis*-1,2-cyclopropanedicarbonyl diazide [Majchvzak, M. W., Kotelko, A., Guryn, R., *Synthetic Communications*, **11**, 493 (1981)], which keeps the diazide in toluene solution at all times, and is unlike other procedures for the trans compound that isolate it as the neat oil [for example, Witiak, D. T., Lee, H. J., Hart, R. W., Gibson, R. E., *J. Med. Chem.*, **20**, 630 (1977)].

It is unknown what initiated the explosion. The cause may have been the shock caused by the Teflon-coated magnetic stir bar being placed into the flask or possibly iron fillings that may have adventitiously been on the stir bar. We hope that others will take note of the extreme explosive hazard inherent in this compound.

Robert E. Johnson
Sterling Winthrop Research Institute
Rensselaer, N.Y.

Catalyst for learning

SIR: David C. Finster in his letter (C&EN, Dec. 21, 1987, page 3) brought out a very important point in his statement, "The rate-determining step in education is not teaching, but learning." In 30 years of teaching I never was able to cover the textbook completely, and in recent years I was covering less than I did 20 years ago (of course the books have gotten larger also). There are suggestions that we need to add things such as polymers, material science, computer literacy, and business to the curriculum in order to turn out well-rounded graduates. I can agree that all of these things would be worthwhile, but the question is how to do it.

To add these other areas on top of the present curriculum requirements is ludicrous. The present students can't or perhaps don't want to learn anything additional. It would require adding another year to the degree, and, considering the attitude of the present-day student, we would have very few chemistry majors. Until the attitude of the public and the students is changed and the importance of a good education is appreciated, asking the students to take more courses and learn more will accomplish little.

I have no good answers to the problem. I must agree with Finster that shoving more information at the student is not going to change the rate-determining step. It will simply give the instructor more material to ask questions about, but the student will not be able to answer them, since additional learning did not take place. What we need is a catalyst that will change the mechanism of our teaching-learning process and allow for additional learning to occur. I doubt that additional science courses will be the catalyst.

Paul R. Wunz Jr.
Retired

Littering space

SIR: Alan Rhodes (C&EN, Feb. 15, page 2) cites Jacques Cousteau as pointing out that the Strategic Defense Initiative tests are littering space with so many thousands of small high-velocity fragments that "if we do not take action, this waste will become an almost impenetrable shield which could prevent, perhaps for a thousand years, our access to space."

But how marvelous! Even if SDI proves impractical, just working on it will put up "an almost impenetrable shield," which of course would wreck intercontinental missiles as easily as it wrecks spaceships.

Still, I would like to see Cousteau's calculations on how many fragments stay in orbit (rather than escape to outer space or burn up in re-entry), how thick they would be in the vast volume of near-Earth space, and what are the resultant changes of collision. I suspect he may be off by a few orders of magnitude.

George W. Price
Chicago

Correction

- Feb. 1, page 15: El Paso Products uses its own proprietary polypropylene technology at its Bayport, Tex., plant; it does not license Union Carbide's process.

Revenues Up Sharply at Biotechnology Companies

With more products coming to market and consequent rising revenues for many firms, some began to show profits in fourth quarter

Food & Drug Administration and Environmental Protection Agency approvals are beginning to have an effect on the fortunes of biotechnology companies. Some of them were able to introduce new products last year and others have products that they expect to begin marketing this year.

As the companies move into commercialization, revenues—especially from product sales—are increasing, and some of the firms are beginning to be profitable. Indeed, Genentech, the industry leader, has proven so successful that it has been able to receive listing on the New York Stock Exchange, a goal to which most smaller companies aspire and an indication that the capitalization of the company is fairly secure.

The result is that combined revenues from 19 biotechnology companies sampled by C&EN moved up 69% in the fourth quarter of 1987 from the similar period a year earlier to a combined total of $168 million. And as a composite, the group registered a profit; combined earnings amounted to $290,000, compared with a loss of more than $31 million in the fourth quarter of 1986.

For the year as a whole, the group recorded revenues of about $516 million, up 41% from 1986. The group's operating loss totaled $20 million, far better than the $67 million loss in 1986.

Much of the improved results in the fourth quarter can be attributed to Genentech, which launched its Activase tissue plasminogen activator, used to reduce blood clots, during that period. Also, the company says, sales increased for its Protropin human growth hormone.

The South San Francisco, Calif.-based company is not underplaying the importance of its results. Robert A. Swanson, Genentech chief executive officer, says, "With the ap-

Fourth-quarter revenues rose for 12 biotechnology companies

	FOURTH-QUARTER 1987						FULL-YEAR 1987					
	Revenues[a]	Earnings[b]	Change from 1986		Profit margin[c]		Revenues[a]	Earnings[b]	Change from 1986		Profit margin[c]	
	($ millions)		Revenues	Earnings	1987	1986	($ millions)		Revenues	Earnings	1987	1986
Amgen	$13.553	$ 0.322	52%	def	2.4%	def	$ 49.378	$ 1.523	40%	283%	3.1%	1.1%
Biogen	2.936	−3.391	48	def	def	def	12.508	−22.602	21	def	def	def
Calgene	2.657	−0.902	37	def	def	def	23.406	−0.641	114	def	def	def
California Biotechnology	2.700	−3.400	−39	def	def	def	11.675	−8.500	−31	def	def	def
Cetus	15.937	−3.633	26	def	def	def	55.065	−9.223	16	def	def	def
Collagen	6.136	−0.688	3	def	def	7.3%	23.871	0.033	2	−99	0.1	9.4
Cytogen	2.486	−2.339	27	def	def	def	11.423	−4.193	154	def	def	def
DNA Plant Technology	1.725	−0.388	−5	def	def	0.8	7.138	−1.048	8	def	def	1.3
Ecogen	1.276	−0.438	8	def	def	5.9	4.283	−4.889	37	def	def	def
Genentech	96.477	27.200	163	750	28.2	8.7	230.543	42.200	72	385	18.3	6.5
Genetics Institute	4.424	−4.113	−28	def	def	def	19.600	−10.444	2	def	def	def
Immunex	4.288	−0.524	37	def	def	def	15.704	−0.175	66	def	def	def
Integrated Genetics	3.307	−1.048	−10	def	def	7.9	12.476	−2.722	23	def	def	def
Liposome	1.191	−1.245	−2	def	def	def	4.032	−6.255	15	def	def	def
Molecular Genetics	2.021	−3.164	−12	def	def	def	8.437	−3.772	−7	def	def	def
Monoclonal Antibodies	2.110	−0.440	11	def	def	def	5.872	11.205	−31	def	190.8	def
Repligen	2.000	−0.923	44	def	def	def	9.743	0.320	125	def	3.3	def
Ribi ImmunoChem	0.307	−0.598	−23	def	def	def	1.564	−1.086	−3	def	def	def
Synergen	2.696	0.002	41	def	0.1	def	9.449	−0.121	19	def	def	3.7

a Includes sales, contract research, royalty, and interest revenues. b Excludes extraordinary credits. c After-tax income as a percentage of sales. **def** = deficit proval of Activase and the benefits it delivers for an improved quality of life for millions of Americans, the promise of biotechnology is now a reality."

Genentech is not resting when it comes to applications of its two products. The company shipped more than $86 million of growth hormone in 1987 and $58 million of Activase. Swanson says that the company is exploring a new use for its growth hormone in adults that will be tested in clinical trials in burn victims. He adds that Activase will be tested in blood-clot-related disorders other than heart attacks, for which it has won approval.

Although Genentech is the most visible of the companies in terms of product sales, it is not the only firm selling products. At Monoclonal Antibodies, Mountain View, Calif., product revenues in fourth-quarter 1987 increased 3.2% to $1.43 million. Thomas A. Glaze, the company's president, comments: "Sales in the quarter reflected particularly strong shipments of Advance (brand) components to Ortho Pharmaceutical. We were not able to begin shipping our new OvuQuick product during the quarter as we had expected, but shipments did commence the first week of January."

At Collagen Corp., Palo Alto, Calif., product sales for the quarter declined to $5.94 million from about $5.98 million in the same period the year before. This may be due for a turnaround, however. The company says that new marketing and sales programs are beginning to show promise, such as doubling of consumer inquiries for product and physician information. Problems came from delays with new products and the costs associated with the sales and marketing plans for the products. Howard Palefsky, president and chief executive officer of the company, says that he believes that these problems will be resolved and that earnings for the company's fiscal year, which will end June 30, will approach break-even.

Besides Genentech, two other companies that were surveyed by C&EN showed profits in the fourth quarter of 1987. Amgen posted earnings of $322,000 in the quarter, up from a deficit in the same period the year before. For the full year, the company's earnings were $1.52 million, a 283% increase from the year before. And Synergen, Boulder, Colo., had tiny earnings of $1800 in the fourth quarter, compared with a $106,100 loss in the same period the year before. For the full year, however, Synergen showed a $121,400 loss.

The biotech firms are all relatively bullish, in spite of continued losses. Larry Soll, chairman and president of Synergen, says, "Synergen experienced strong growth in 1987. We significantly accelerated preclinical studies of our therapeutic products and now have the pilot production facility and organization necessary for successful human clinical testing. In the past few months, we manufactured significant quantities of our pharmaceutical products for evaluation and testing. Our first commercial product, a genetically improved strain for the production of riboflavin, is now being produced by Coors Biotech Products Co."

At Cytogen, president and chief executive officer Ronald J. Brenner, says, "Results to date with OncoScint (cancer imaging agent) in human clinical trials are very encouraging and suggest that our cancer imaging agent should improve management of the cancer patient. In 1988 we intend to expand both the breadth and scope of the clinical evaluation of Cytogen products, and thus we are forecasting a continuation of significant investment spending." He notes that 1988 will be a year of significant progress toward market introduction of Cytogen products.

William Storck, New York

DSM, Kemira to swap fertilizer operations

Restructuring of Western Europe's troubled fertilizer industry continues apace. The latest move being contemplated entails a portfolio swap between DSM of the Netherlands and Finland's Kemira. If the plan materializes, it will mark a further step in Kemira's strengthening of its role as supplier of compound fertilizers based on nitrogen, phosphorus, and potassium.

DSM, for its part, aims to concentrate on the high-nitrogen sector of the market. It will gain total ownership of an ammonia operation at Geleen, the Netherlands, in which Kemira now has a one-third share, thereby raising its captive ammonia capacity at the site to 800,000 metric tons. And by quitting the phosphate-based fertilizer business, DSM no longer would have to face the growing environmental concern over cadmium pollution (C&EN, March 14, page 8). DSM uses Moroccan phosphate rock that has a relatively high cadmium content. In contrast, rock from Kemira's own Finnish mine is extremely low in cadmium.

Through acquisition of DSM's Rotterdam operations, Kemira will gain ownership of a 220,000 metric-ton, wet-phosphoric-acid plant. It will be the company's first move into phosphoric acid production outside Finland, where it operates units at two sites with a total annual output capability of 250,000 metric tons.

In addition to phosphoric acid, DSM makes ammonium nitrate, nitric acid, and urea at Rotterdam. And its half share of a 400,000 metric-ton-per-year ammonia plant there—a joint partnership with West Germany's BASF—will be transferred to Kemira. Nearby, Kemira has its own 550,000 metric-ton-per-year ammonia plant.

The Finnish state-owned company also will gain a bigger share of the U.K. business through DSM's UKF operations at Ince, Cheshire, on England's west coast, where ammonia, nitric acid, and compound fertilizers are made. These will fit in neatly with Kemira's own fertilizer production on England's east coast. Its U.K. expansions include a 200,000 metric-ton-per-year ammonia plant now nearing completion.

During the past few years, Kemira has made a strong push out of Finland and onto the European fertilizer scene. In Belgium, it acquired Société Carbochimique with plants at three locations. In Denmark, it took a majority holding in Superfos. And in the U.K., it purchased L&K Industries.

Dermot O'Sullivan, London

4/7/88 A1250-1

APRIL 4, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR6614SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Cosmetics

Chemical specialties that do more than cover up Page 21

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 14
CENEAR 66 (14) 1–72
ISSN 0009-2347

APRIL 4, 1988

News of the Week

- **Most chlorofluorocarbon producers reacted favorably to Du Pont's call for phasing out production of CFCs, implicated in the global loss of ozone.** **Page 4**
- **The Army's plans for a biological warfare testing facility in Utah are drawing heavy criticism from an environmentalist, Congressmen, state officials, and the Mormon Church.** **Page 5**
- **U.K. chemical capital spending for the 1988–90 period will be up a hefty 36% over the 1985–87 outlay, according to a Chemical Industries Association survey.** **Page 5**
- **Koppers is receiving assistance from state officials in Pennsylvania in its battle against a takeover bid from BNS Inc., which is controlled by British builder Brian Beazer.** **Page 6**
- **Government and industry efforts to improve energy efficiency have lost momentum, need revitalizing, says a study by Worldwatch Institute, a private research group.** **Page 6**

Business

Hoechst Celanese merger has boosted Hoechst's participation in U.S. markets, says U.S. company president Ernest Drew. **Page 9**

Government

Proposed research budgets for national labs are too small, according to lab directors' testimony at Congressional hearings. **Page 13**

Technology transfer from federal labs still has problems, according to a General Accounting Office study. **Page 14**

Science

Synthesis of first compound containing a krypton-nitrogen bond is a significant advance in noble-gas chemistry. **Page 16**

Technology

A new video-based particulate-monitoring system provides images of process streams in motion. **Page 20**

Books

"The Metamict State" by Roald Hoffmann bridges the gap between science and the humanities with poetry for all. **Page 46**

Cover: Photo by Arthur Tilley/Uniphoto Picture Agency

Letters 2

Concentrates
Business 7
Government 12
Science/Technology 15

The Departments
New Products 45
Meetings 49
Awards 70
Newscripts 72

Product Report

Traditionally used to enhance appearance, cosmetics today are moving toward more body-care uses, such as prolonging or protecting the health of the skin or hair. **Page 21**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gisi (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 71)

LETTERS

CHEMICAL SAFETY

Unstable metal nitrates

SIR: The addition of an aqueous solution of SnF_2 to an aqueous solution of some divalent metal nitrates $M(NO_3)_2 \cdot xH_2O$, (M = Sr, Ba, and Pb) produces the immediate precipitation of tin(II) fluoride containing materials that are stable in air at room temperature [Donaldson, J. D., et al., *J. Chem. Soc.* (A), 1821 (1967); Denes, G., et al., *C. R. Acad. Sc. Paris*, **280C**, 831 (1975)]. I wish to report here the occurrence of the explosion of the product obtained from a similar reaction using magnesium nitrate hexahydrate.

A 1.5M aqueous solution of SnF_2 (3.205 g in 10 mL) was added dropwise (10 mL in 90 seconds) to an aqueous solution of $Mg(NO_3)_2 \cdot 6H_2O$ (2.622 g in 10 mL) upon stirring, at room temperature, in a Nalgene beaker. Contrary to the cases of Ca, Sr, Ba, and Pb, no immediate precipitation was obtained. After evaporating seven days at room temperature, a wet white solid was obtained. In order to accelerate drying, the beaker was placed on the roof of a drying oven, at 47 °C. After 80 minutes, it was allowed to cool to room temperature and a weight loss of 0.367 g was measured; however, the white solid was still wet. To accelerate further the drying process, the product was scraped from the bottom of the beaker and cut into small pieces with a spatula. As I was cutting it, the white wet solid suddenly exploded violently. A brownish gas was evolved, most likely NO_2, and a significant amount of the solid was blown out of the beaker. To my surprise, I realized that there was no more wet white solid, but instead a large amount of khaki-colored fine dry powder, which turned bright yellow overnight. The beaker was cold and undamaged. My fingers that were holding the spatula showed a slight brownish skin color on the side exposed to the beaker, probably surface skin oxidation by NO_2 vapor. It did not cause any discomfort and disappeared in a little less than a week. ^{119}Sn Mössbauer spectroscopy showed that only tetravalent tin was present, similar to that found in SnO_2; however, x-ray powder diffraction showed the sample contained no crystalline SnO_2.

The white wet solid was probably a nitrate-containing phase, highly unstable when submitted to a mechanical shock, even moderate, or when exposed to atmospheric oxygen. Explosion of silver nitrate being recrystallized from ethanol has also been reported (C&EN, Jan. 12, 1987, page 2) to occur upon application of a minor mechanical energy using a spatula. This further stresses the danger of working with nitrates and metals in fairly unstable oxidation states. Violent oxidation of tin(II) to tin(IV) with simultaneous reduction of nitrogen(V) (NO_3^-) to nitrogen(IV) (NO_2) occurred. Fortunately, the product was contained in a nonsealed container preventing pressure buildup and a more violent explosion. The lesson to be remembered is that some of these "innocentlike" reactions can be potentially dangerous.

Georges Denes
Assistant professor
Concordia University, Montreal

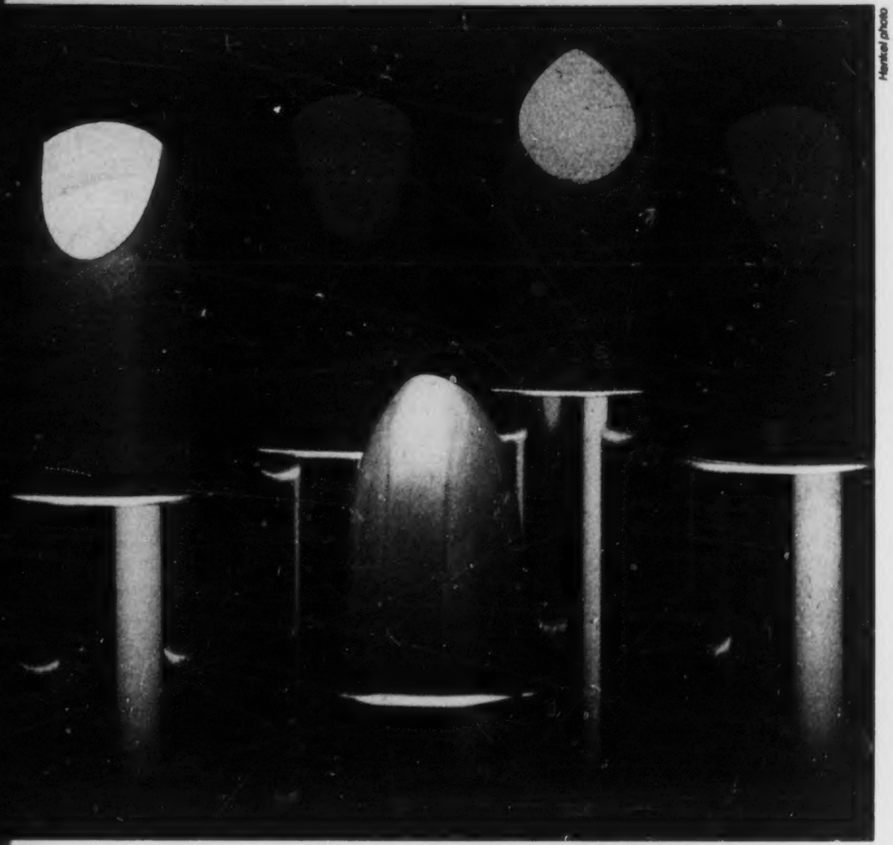
Academic job market

SIR: On behalf of all of the recent chemistry Ph.D.s in search of an academic career, we wish to call attention to a portion of the ACS Comment by Paul Gassman (C&EN, Dec. 14, 1987, page 51). The conclusion reached by Gassman that "there are more than twice as many faculty openings than there are individuals who desire academic positions" is shaky at best. We only wish there were two openings for every applicant. Our recent experience of applying for tenure-track physical chemistry positions leads us to believe that there are at least three or four applicants per job. Last year we each applied for about 25 physical chemistry positions. Based on our rejection letter statistics, there were at least 100 applicants for most of these positions.

Gassman attributes the presence of so many vacancies to low-quality applicants. This may explain the vacancies at some top-ranked institutions, but it cannot explain the presence of the large number of openings at smaller colleges and universities. Research-oriented candidates are often rejected by these institutions for being "overqualified." It seems that many departments do not have a well-defined policy for promoting research as an essential part of the undergraduate and graduate educational process.

The main issue we wish to raise is that things are not nearly as simple as a quick analysis of percentages and numbers would indicate. There are many well-qualified individuals looking for academic jobs: men and women hoping to devote their energies to teaching and

PRODUCT REPORT



Henkel photo

Cosmetics

Body care eclipses coverup in some uses

Patricia L. Layman, C&EN London

Historically, cosmetics and toiletries have been tools of adornment, for such uses as adding color to the face, cleansing the hair and body, and whitening the teeth. But lately, there has been a decided move from just "cosmetic" adornment for the sake of esthetics toward more scientific, or quasiscientific, uses that do something good for the human body.

In this new genre of products, skin-care formulations aim to prolong the good health and appearance of skin. Sunscreen products protect against ultraviolet rays and perhaps against skin cancer. Even simple shampoos aim to protect and condition the hair through the cleansing process.

With these changing demands on the cosmetics and toiletries business, corresponding demands arise for the suppliers of raw-material ingredients. Cosmetics companies are dependent on what suppliers can come up with, so are pressuring for more, better, and, increasingly, milder ingredients.

It is certainly an end-use market for which new developments are worth working on. According to one estimate, U.S. retail sales of cosmetics and toiletries last year amounted to $23.7 billion. Retail sales in Western Europe weren't far behind at nearly $19 billion, and in Japan they probably approached $14 billion. Add another $12 billion to $15 billion estimated for the rest of the world, and the grand total spent by people around the world for "adorning" themselves comes to about $70 billion.

In turn, global sales of the chemical ingredients in cosmetics probably represent about 10% of that market, or about $7 billion, if earlier ratios that consultants such as SRI International worked out still hold. It is a widely fragmented market, with more than 1000 chemicals employed routinely as cosmetic ingredients. Many more are used less frequently or only in certain countries. In the U.S., at least, an overall yearly growth rate of just under 6% in current dollars is expected to 1990.

Consultant firm Frost & Sullivan, in a report on cosmetics raw materials published last year, argues that fragrance ingredients are the crucial materials for cosmetics, with the influence of scent extending far beyond that of the classic perfume blends. In fact, the consultants say, almost as many "perfume and aroma chemicals are going into haircare products as into perfumes and colognes themselves." As a group, only oral hygiene products—toothpastes, mouthwashes, and the like—"are without fragrance ingredients in their formulations." Even that proves the point, however, because that category is highly dependent upon flavoring materials, which are basically a subset of fragrances.

Fragrances account for nearly a quarter, by value, of all ingredients used in cosmetics and toiletries, although when measured by weight, they constitute far less than 1% of all ingredients. They have the highest cost per pound of any chemical or ingredient class: an average of $22 per lb for fragrance components, although some of the rarer essences or oils can cost up to $3000 per lb. Lab emphasis is on producing synthetics to replace natural substances,

Distinction between cosmetics and pharmaceuticals is narrowing

Every few years there is a spate of quasidrug products claiming to do all sorts of good things, and those claims are usually shot down quickly by the Food & Drug Administration.

The latest batch of such products has been the anti-aging products, which by one estimate have already rung up sales of $100 million in the U.S. alone, out of a $1.8 billion skin-care market. One of the first of this group was Glycel, from Suisse Laboratories in Europe and Alfin Fragrance in the U.S., marketed under the aegis of heart surgeon Christiaan Barnard.

This was followed by Christian Dior's Capture and Lancôme's Niosome. Dior claims that Capture is especially efficacious because of its method of incorporating liposomes into a skin-care formula. The company says its "complex liposomes" are made of natural microencapsulated phospholipids that have a molecular structure identical to that of cell membranes. Thus, says Dior, they can biologically blend with the cellular membrane to restore fluidity and promote the exchange of vital elements.

Lancôme's Niosome contains microscopic lipidic spheres said to match the skin's intercellular system while also transporting active elements to the more distressed areas of the skin, counteracting the early breakdown of cell cohesion and treating the underlying causes of aging skin. And similar claims hold good for others of the new generation of anti-aging creams marketed by cosmetics giants Chanel, Charles of the Ritz, Esteé Lauder, and Guerlain.

One of the most direct scientific approaches has been that of the Japanese cosmetics giant Shiseido, with its B.H-24 treatment fluids. These are sold in prestigious London department stores for more than $100 for two 1-oz bottles. The package labeling proclaims the presence of the sodium salt of hyaluronic acid, at 0.12% for the day essence lotion and 0.15% for the night treatment fluid. Lots of cosmetics packages, of course, contain all sorts of fancy products. But very rarely do you find a package—handsome, matte-silver-coated plastic case—emblazoned with the molecular structure of the product's active ingredient, as Shiseido's package so strikingly does.

Use of the representation of the hyaluronic acid molecule as a marketing point has intrigued chemical suppliers in Europe, none of whom can remember quite the same emphasis being put on the chemistry of a product, particularly in an environment where "natural" products are highly popular. One possible explanation for the decision, says one supplier, is that "You can do this when you sell through a department store, and the counter girl can explain it. You can play more the technical game. Besides, if you charge $50 for a little tube of cream, you have to say something to make it believable."

Says Shiseido in an advertisement clearly directed at an American audience but published in a glossy U.K. publication, "Two minutes a day. Radiant, healthy, younger-looking skin. Shiseido B.H-24. Just a few drops of moisturizing, protective Day Essence in the morning. The same amount of revitalizing Night Essence before bed. Shiseido understands precisely how your skin works, day and night. So they have simplified the science of caring for it. Using Japan's most advanced biotechnology, Shiseido scientists have duplicated the moisture-binding substance plentiful in infants' skin. This exclusive humectant fortifies every single drop of B.H-24: two perfectly compatible formulae for round-the-clock treatment. Your time is as precious as your skin. Now you can make the most of both."

Hyaluronic acid as a humectant is one of the latest magic chemical ingredients for cosmetics companies to turn to. However, one indication that this area of cosmetics may be moving from art to science is the willingness of Johnson & Johnson to go through the time-consuming (and dollar-consuming) new drug application course for its retinoic acid-based cream for removing wrinkles—a course not lightly chosen.

Marketers have had to walk a fine line because of FDA's active interest in promotion claims. Late last year, for example, FDA stepped in and told several cosmetics companies their claims were off-base: relabel or reformulate. And the agency sent letters to a number of other companies cautioning that claims were borderline drug claims.

Retinoic acid—vitamin A—has been used as an acne treatment for many years, and recent research also has indicated that it may be effective in treating serious, rare forms of psoriasis. The wrinkle-removing aspect, however, is new.

The question that Johnson & Johnson will be attempting to answer in its new drug application is whether it works. The next question then will be, if it does work, would its near-relatives and derivatives?

Says one consultant, "Other than retinoic acid, people are playing games with close relatives, such as retinyl palmitate. The Germans use retinyl propionate; they have used retinoic acid itself in creams a long time. In the U.S., it is for prescription only, for acne. There is

---

whose supply can be erratic and quality inconsistent.

Synthetic surfactants are the largest cosmetic raw material segment, with estimated 1988 U.S. sales of 550 million lb, says Mark Chandler, an analyst with consultants Kline & Co. Shampoos provide the largest outlet for these. In order of volume, the three major surfactants used in shampoos are lauryl sulfates, lauryl ether sulfates, and α-olefin sulfonates. Smaller but still significant surfactant groups include amphoterics and sulfosuccinates.

In Western Europe, surfactant sales for cosmetics and toiletries totaled slightly more than 300 million lb last year—about 7% of total surfactant consumption—valued at about $250 million. Anionic surfactants, used primarily in shampoos and bath products, led the way with 207 million lb worth $141 million, followed by nonionics, which feature in creams, shampoos, and bath products, at 62 million lb valued at $55 million. The more specialized surfactants such as amphoterics for shampoos and bath products accounted for 26 million lb, valued at $41 million, and cationics, which go mostly into hair conditioners, 6.6 million lb valued at $11 million.

Advertising and promotion continue to be extraordinarily impor-

B.H-24
Day/Night Essence
Bio Essences Jour et Nuit
SHISEIDO

B.H-24 brochure depicts molecular structure of product's active ingredient

a great trade in Tijuana for Americans buying Johnson & Johnson's retinoic cream there without prescription. It's slightly hogwash. Marketers are playing at the fringes of the retinoic acid publicity that Johnson & Johnson got, with products for which they don't need a new drug application."

One ingredient supplier points out that retinoic acid has long been used by many researchers as a reference standard for cell-renewal products, because of its effects on skin cells. "It's a systemic effect," he says. "One of the mechanisms is revving up the skin cells, so they slough off faster. When a person stops using it, the skin is in better condition." Some researchers had looked at retinol, the alcohol version, as a less irritating chemical, but the effect is apparently not there. "What FDA is worried about is that retinoic acid really revs up the cells, increasing the turnover of cells. The concern is to make sure that the cell turnover rate will decrease when you stop; otherwise, you wind up with what is basically a skin cancer."

All the studies have been for treating chronic acnes, without scar tissue. "For wrinkled, normal skin, you could probably cut the concentration way down," he says, probably to about 0.01% or even less. Such low concentrations would be fairly innocuous and cause little or no irritation, especially if compounded into a nice cosmetic vehicle. He predicts that Johnson & Johnson will move as quickly as possible with its trials. "People here are clamoring for it. These will be the next wave of products."

Similarly, Upjohn is seeking the seal of respectability for its minoxidil as a baldness treatment. The material, which has stimulated considerable hair growth in about a third of those who use it, is currently being sold under the tradename Regaine in Canada and Europe, but it is awaiting approval in the U.S. as a prescription drug.

Other marketers, with various herbal or synthetic products, stop short of making claims that they can get hair to grow again, thus avoiding the drug licensing process. Instead, they promise scalp treatments to lengthen the natural hair-growing cycle, thereby improving the condition of existing hair.

It's all for a good cause, as they see it. Thinning hair affects half of American men by their 50th birthday, and a smaller percentage of women. Spurred by the promise of minoxidil, U.S. sales of cosmetic hair treatments ultimately could reach $1 billion a year, analysts say, up from $20 million actually sold before Upjohn submitted the material to FDA for approval in late 1985. Estimates of potential annual sales for minoxidil itself range from $50 million to $250 million. The tonics and lotions are not cheap. The cost of minoxidil, meant to be taken on a permanent basis, is expected to be about $800 a year.

tant in the cosmetics and toiletries industry. Consultants at Business Trend Analysts, for example, point out that the early marketing campaign for Calvin Klein's Obsession perfume in 1985 cost $17 million. "Is this sort of advertising budget indicative of future expenditures of upscale fragrances?" they ask rhetorically. And the answer quite probably is yes—but worth every penny if the product is a winner. After all, back in 1982, Opium fragrance from Yves St. Laurent was estimated to gross over $100 million a year, with designer perfumes accounting for nearly half of total perfume and fragrance sales in value terms.

However, the industry increasingly values any help it can get from the scientific realm, as it emphasizes products such as skin care and sun protection, even if this conflicts with the attractiveness of claims

Nitrile Hydrogenation.

Powerful chemistry to produce the specialty amine you need.

Our two-step process uses acrylonitrile to produce specialty nitriles which can be converted to primary, secondary or tertiary amines. Employ our expertise at the start of a commercial idea, and we'll develop the most efficient route to your new product.

The resources we can devote to your project include one of the largest and most flexible hydrogenation facilities in North America, a pilot plant and fully dedicated nitrile handling equipment. Our expert team of scientists work in some of the most modern and fully equipped laboratories in the industry.

For acrylonitrile derivatives, and for all your carbon-nitrogen-based chemical needs, call us at 800-345-3148.

©Air Products and Chemicals, Inc., 1988

More than chemicals. Chemistry.

AIR PRODUCTS

CIRCLE 1 ON READER SERVICE CARD

about "natural" products or ingredients. As Joel Houston, a consultant with Colin A. Houston & Associates, puts it, "The industry acknowledges that people respect 'scientifically proven' for a scientific or quasiscientific claim, more than the 'natural' claim. But it's awfully hard to get a scientifically proven claim."

Nonetheless, cosmetics marketers are striving for just those claims, as they follow and strengthen the trends affecting the industry. Skin-care products show increasing use partly because of an increasing concern about health and beauty, and partly because some consumers are starting to use these products earlier, as standards of living rise. There is a general concern about the damage to skin from overexposure to the sun over the years. And increasing numbers of male consumers are being lured to skin-care products and grooming aids.

Driving many of these trends is the inescapable demographic change affecting much of the industrialized world: the graying of its populations. In the U.S., women aged 35 to 44 currently represent the fastest-growing segment of the population. The most rapid growth in the 1990s, however, will be the sector of the populace aged 45 to 54. By the year 2000, the largest single age group will be the senior segment, aged 55 and older.

Demographics are already playing a significant role in the industry's growth. As the vast postwar baby-boomers move through life, with the discovery of distinguished silver bits at the temples, or the deepening laugh lines around the eyes, skin-care and hair-care products suddenly become rather more interesting than before. The emphasis is on mildness—a caress rather than a vigorous scrub.

In addition, with disposable income increasing, people can afford to take better care of themselves. As Kline consultants point out, marketers respond to this trend by developing products targeted at this group, and more likely specific segments of the 30-plus populations. For example, toothpastes that promote specific properties such as plaque and tartar control are of greater importance to older consumers than cavity prevention. Similarly, women's facial treatments, in particular the prestige lines, are fueled by heightened consumer interest.

Haircare dominates U.S. cosmetics and toiletries

$ Billions	1987 retail sales
Hair care	$5.398
Perfumes & colognes	3.410
Skin care/emollients	2.530
Hand, face & body soaps	2.220
Oral hygiene	2.183
Eye makeup	1.746
Deodorants, antiperspirants	1.610
Lip care	1.094
Face makeup	0.933
Nail care	0.634
Shaving, depilatories	0.582
Sunscreens, tanning products	0.487
Powders	0.358
Miscellaneous	0.495
TOTAL	$23.680

Sources: Frost & Sullivan, C&EN estimates

In hair care—the largest cosmetics and toiletries segment—mildness is the word; more frequent shampooing leads to demands for less stripping surfactants. How manufacturers in various countries accomplish this will often differ markedly.

In the U.S., for example, probably 70% of shampoos are clear and only about 30% pearlescent (that excludes the antidandruff shampoos, which are opaque formulations because the active ingredient isn't soluble). Peter Walters, manager of personal-care and cosmetics ingredients for ICI Americas, explains that "Apparently in shampoos, adding pearlescent agents gives the impression that this is not a pure clean product, that it leaves something on the hair. We want something 'squeaky clean,' and clear reinforces that image."

Kline's Chandler adds: "In the U.S., pearlescents are perceived as having a conditioning effect. Clear equals clean; cloudy or pearly equals

"FORT IN FAR SPAIN"
W.W. Porterfield
Dept. of Chemistry, Hampden Sydney College

There's no telling where "nitroparaffins" will take you. And the real CH_3-NO_2, CH_3-CH_2-NO_2, CH_3-CH_2-CH_2-NO_2, and CH_3-$CH(NO_2)$-CH_3 may lead you to the outposts of your chemical mind. . .where you'll tilt with heroic discovery. For a guide to chemical conquests or a free sample, contact W.R. Grace & Co., Organic Chemicals Division, 55 Hayden Avenue, Lexington, MA 02173, *1-800-GRACE NP.*

There are untold ways to combine nitroparaffins, but only one way to buy them:

GRACE
ORGANIC CHEMICALS

CIRCLE 18 ON READER SERVICE CARD

conditioning. A lot of people don't like the idea of having the two-in-one product. There's not the same perception in West Germany and the rest of Europe."

In fact, market data at Henkel, a West German chemical producer, indicate that probably 80% of all shampoos there are pearlescent, including nearly all the cheaper private-label products and three quarters of the more expensive shampoos. There, the perception goes, "clear equals empty." Much better instead, the thinking goes, to have a shampoo packed full of good things for the hair, to care for it while cleaning it.

And in one of the newest markets for sun-care products, protection is the major preoccupation. Once the province of the glamorous ski bunnies at St. Moritz or the bronzed surfers on Waikiki beaches, sun-care products have become a significant hot market after a period of quiet during the 1970s and early 1980s.

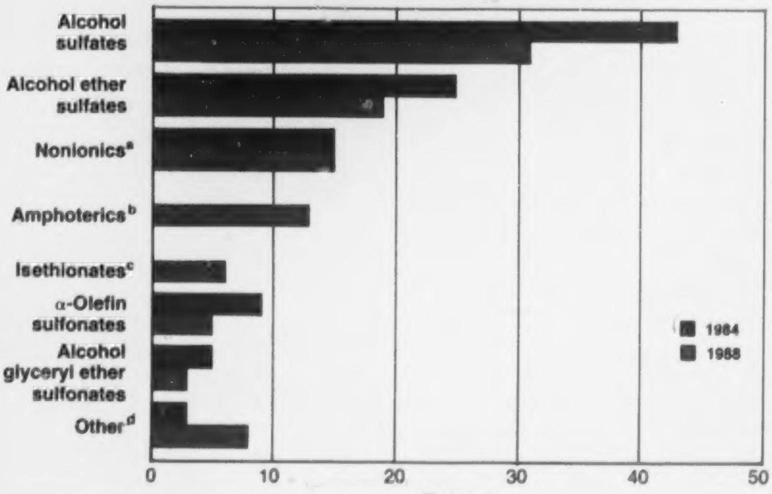
At about the turn of the decade, sunscreen makers were tapped by the Consumer Product Safety Commission, which decided to encourage sunscreen use with informative labeling systems. It was a marketer's dream to be able to say something to the effect "liberal and regular use may help reduce chances of premature aging and wrinkling of skin, and skin cancer, due to long-term overexposure to sun."

The sun protection factor (SPF) numbering system was developed to relate protection to natural skin protection. A suntan lotion of SPF 4, then, would provide four times the skin's natural sunburn protection. A sunscreen cream of SPF 15, the maximum in the early days of the system, was designed essentially as a sun block.

Sunscreen active ingredients were formulated into the obvious products—suntan lotions and creams, sun block creams, and lip protection creams. But eventually marketers began putting them into other cosmetics and toiletry products as well—cosmetic foundation creams, for example, good for a consumer to wear in the yard to do gardening, or out and about in general activity—as awareness of the problem of skin cancer grew.

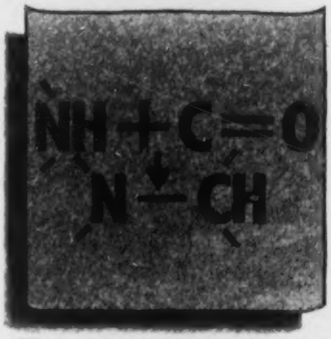
Now, says ICI's Walters, the sun-care market is "in a regulatory turmoil," as some companies promote products with SPF ratings of 30, 39, and even more. The Food & Drug Administration, he points out, is questioning whether ratings beyond about 15 are realistic. "It has become just a numbers game. You can demonstrate this in a laboratory, but

U.S. cosmetics and toiletries industry's surfactants use pattern has changed markedly



a Includes alkanolamides. b In 1984, included in "other" category. c Synthetic soaps. d Includes alcohol ethoxylates and fatty amine oxides. **Sources:** Kline & Co., C&EN estimates

Reductive Amination.



Creative catalysis coupled with a multipurpose hydrogenation facility.

Being experts in catalysis and process research means we can help find the most efficient route to the new specialty amines you need.

What's more, our facilities include modern research labs, a pilot plant and one of North America's largest batch hydrogenation plants. An expert team of scientists and commercial development specialists is dedicated to seeing that every project is handled in the most economically and technically effective way.

From R&D through scale up and commercialization, we can take your product from start to finish. This can cut your workload, capital investment and ease the demand on your research and manufacturing resources.

For specialty amines, and for all your carbon-nitrogen-based chemical needs, call us at 800-345-3148.

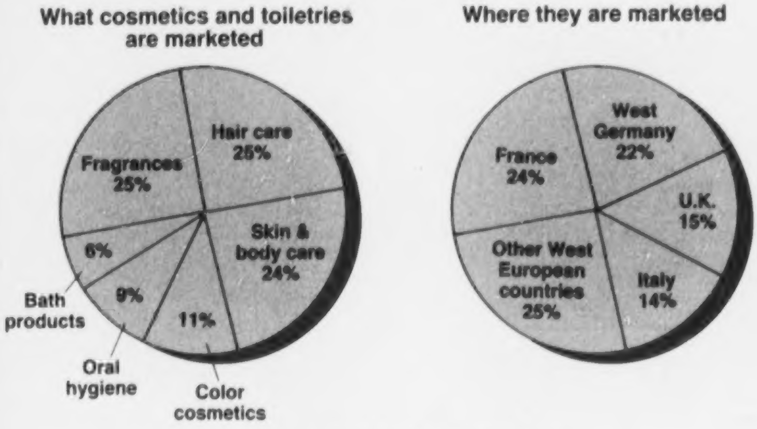
©Air Products and Chemicals, Inc., 1988

More than chemicals. Chemistry.

AIR PRODUCTS

CIRCLE 2 ON READER SERVICE CARD

West European cosmetics market



1987 retail sales = $18.9 billion

Sources: Euromonitor, Frost & Sullivan, C&EN estimates

it is meaningless. People are not that much exposed," he says. On the other hand, "dermatologists are saying that any incremental benefit is an improvement. FDA probably will make a ruling soon on what the upper limit should be."

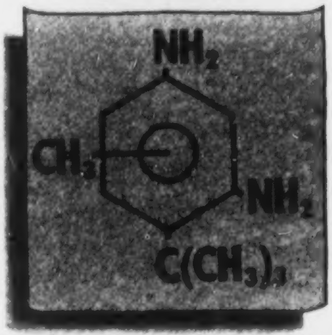
In the meantime, he believes, there is some movement away from octodimethyl *p*-aminobenzoic acid (PABA), one of the more popular sunscreen active ingredients, because of toxicity concerns. "There is a lot of product reformulation as people are getting ready for the summer. They're using methoxy cinnamate compounds and other sunscreens. We have programs under way on the benzophenone and cinnamate markets, and a program to investigate new sunscreen materials for the 1990s and beyond. The market had been fairly static for a while."

In some respects, this reformulation is a U.S. trend. Says Walters' colleague Jean-Marc Suter, general manager for surfactants at ICI Europa, "In Europe, the market is mostly a range of cinnamates. Givaudan is the main supplier. In the U.S., it is benzophenones, with the largest supplier Van Dyke. The trade in Europe believes cinnamates are safer, maybe because Givaudan has promoted them so long. Who knows? Perhaps it is more a historical reason than scientific."

Just as trends are moving through the cosmetics and toiletries industry, similar sorts of changes are occurring throughout the world of ingredient suppliers. And many of them cover the general notion of safety and efficacy.

Hans Hogeweg, general manager for surfactants and additives at Akzo Chemie, explains how Akzo has tackled the problem. "In general for all our products for personal care, we can state four points," he says. "One, all new ingredients—raw materials—for cosmetics must be mild, free from dermatologically harmful by-products, causing no allergic reactions. Two, they must be at least of 99.99% purity, and free of toxicologically harmful by-products. Three, they must have high efficiency: the lower the dose, the better, as there will be lower side effects. And fourth, they must be internationally accepted or allowed. This is a huge problem. We joke that in 10 years, we will have to deal only with Unilever, Procter & Gamble, and Henkel; they will have bought up all the other cosmetics companies. We have to have material approved all through the world, so there can be international formulations. The costs of each formulation are so high, companies are getting away from local formulations. This, in turn, is a cost for us, and restricts the raw materials tremendously. But we have a global organization, and can service this.

Tertiarybutyl-toluenediamine.
(tBTDA)



A proprietary aromatic diamine made via novel alkylation chemistry.

tBTDA is only one of many unique and never-before-available diamine or diamine derivatives made possible through Air Products' new alkylation technology.

This new molecule is characterized by its differentially reactive amine groups and offers performance advantages in many applications, including:

☐ Urethane elastomers
  - Cast
  - RIM
  - Spray
☐ Epoxies
☐ Coatings
☐ Antioxidants

For more information on tBTDA and for all your carbon-nitrogen-based chemical needs, write Air Products and Chemicals, Inc., Industrial Chemicals, Allentown, PA 18195, or call 800-345-3148.

©Air Products and Chemicals, Inc., 1988

More than chemicals. Chemistry.

AIR PRODUCTS

CIRCLE 3 ON READER SERVICE CARD

Barbara Bordnick photo

Model applies new Avon Color line of eye pencils

another aired concerns about the use of sodium lauryl sulfate in toothpastes.

According to Karl Raabe, a product manager for Henkel's cosmetics and pharmaceuticals products group, the dioxane story is not new. "The problem of dioxane, which can be formed from ethylene oxide during the process of ethoxylation, has been known since the 1970s, and we have all been working on it, doing a lot even before that Monitor television show in September '86," he says.

"The Ministry of Health has said cosmetics shouldn't contain more than 500 ppm of dioxane. Well before 1986, the industry took relatively quite high amounts down to a better level—several thousand ppm down to about 1000 ppm. And the tendency has been to make a level of about 50 ppm acceptable."

Nowadays, he says, there are a number of different trends. For example, some cosmetics companies don't want any dioxane contamination, so they must buy the corresponding raw materials. "To avoid any dioxane, you must take those materials free of ethylene oxide—alkyl sulfates, for example, alone or in combination with amphoterics, succinates, and so on," says Raabe. "A few other surfactants may be used for this purpose, but in comparison with these, ether sulfates have a big advantage in skin and mucous-membrane compatibility."

Says Raabe: "We officially guarantee 500 ppm maximum dioxane content in our surfactants. However, research is still continuing and getting better results. We are actually far below 500 ppm, calculated on 100% active matter." For example, he says, if an ether sulfate with 50 to 100 ppm of dioxane were combined with other ingredients so that it constituted 10 to 15% of the formulation, the actual concentration would be getting close to the 10 ppm level. It is not just Henkel doing this, he adds; the industry's efforts to bring in lower dioxane levels is being driven by the industry association for textiles, leather tanning, and detergents.

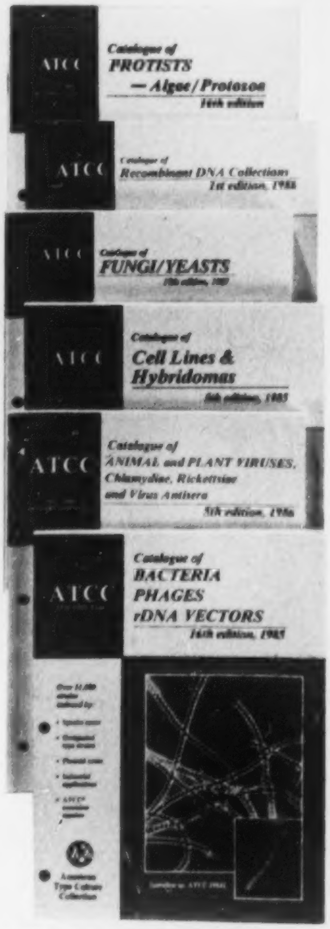
As for the Monitor show on toothpaste, it was aired, as the others, only in West Germany. But the resulting controversy was picked up throughout Western Europe, with varying degrees of consumerist agitation about the surfactant. The main concern of the television show was a worry that the material is "an aggressive surfactant" that could cause a cytotoxic reaction in the mouth, or perhaps contribute to periodontal disease. Why, the show's editors asked with somewhat sinister implications, did some toothpastes have up to 7% of the surfactant,

For Quality Cultures, Come to the

Source

Over 40,000 original ATCC® strains

Algae
Antisera to Viruses
Bacteria and Phages
Cell Lines
Chlamydiae
Cloned Genes
Cloned Viruses
DNA Probes
Fungi
Hybridomas
Libraries
Oncogenes
Phage Vectors
Plasmid Vectors
Protozoa
Rickettsiae
Viruses
(animal and plant)
Seeds
Yeasts


ATCC
Catalogue of PROTISTS — Algae/Protozoa
Catalogue of Recombinant DNA Collections 1st edition, 1986
Catalogue of FUNGI/YEASTS
Catalogue of Cell Lines & Hybridomas
Catalogue of ANIMAL and PLANT VIRUSES, Chlamydiae, Rickettsiae and Virus Antisera 5th edition, 1986
Catalogue of BACTERIA PHAGES rDNA VECTORS

American Type Culture Collection

12301 Parklawn Drive
Rockville, MD 20852
(301) 881-2600

CIRCLE 39 ON READER SERVICE CARD

some about 2%, when the average was 1.5%?

All toothpaste manufacturers and surfactant suppliers were distraught by the attack on sodium lauryl sulfate, which has been used for decades, worldwide, in toothpastes. Henkel, however, was probably most upset and indignant, because of the television editors' casual use of its tradename Texapon—used also for a variety of surfactants for cosmetics—as a generic term for sodium lauryl sulfate, without any indication that there are many other suppliers throughout the world. The company was also indignant over taking out of context Henkel's test data.

Says Raabe: "We use sodium lauryl sulfate as a comparison, because of its known levels of irritancy, and so on. This is quite normal. You must always look at the context of the application."

Partly as a result of these kinds of controversies, some cosmetics companies are turning even more heavily to the "natural concept." For example, in West Germany, Wella—historically a hair-care company but now diversifying into other sectors of cosmetics and toiletries—has launched a premium shampoo, Sanara, with that kind of promotion. Key to the advertising campaign: "It's not important what is in the shampoo, it's important what is not in the shampoo. More than a touch of nature."

At present, "naturals" are spotty across Western Europe, but where they have made it, they are very popular. For example, in the Netherlands, natural cosmetics at health products shops are booming. Packaged in little brown pharmacy bottles, they are sold at premium prices. And in the U.K., Body Shop, which sells naturals in attractively pared-down packaging, is one of the retailing success stories of the decade.

There still is a need, however, for scientific reinforcement. Says Martin Borchers, marketing director in Henkel's Oleochemicals Division, "The cosmetics industry definitely is becoming more sophisticated. They are looking for more detailed information. As long as dioxane, for example, is a concern, they want the analysis, with basic research data."

As the cosmetics industry itself becomes more global, suppliers must think more internationally. Walter Schlaugh, vice president and general manager of National Starch's Resins and Specialty Chemicals Division, points out that the latest generation of mousse products started in Europe, then came to the U.S., and went on to the rest of the world. "You don't know where the next one will come from," so a marketer must keep alert to possibilities, he says.

For small suppliers, that is becoming increasingly difficult, and it points out one of the structural

EXXAL® Guerbet Alcohols from Exxon Chemical Company:

HIG[illegible], NON-WAXY AFTERFEEL AND OTHER [illegible] PROPERTIES FOR YOUR PERSONAL CARE FORMULATIONS:

EXXAL® Guerbet Alcohols are uniquely designed, high purity liquid alcohols that offer many valuable properties such as:

- Low skin and eye irritation characteristics
- Non-waxy afterfeel, unlike other fatty alcohols
- Excellent lubricity for high initial slip in creams, lotions and sticks
- High miscibility with cosmetic ingredients for solubilizing and coupling characteristics
- Three molecular weights to choose from: isocetyl, isostearyl, isoarachidyl alcohols

EXXAL GUERBET ALCOHOLS: UNIQUE, AVAILABLE, AFFORDABLE, CONSISTENT QUALITY

EXXAL Guerbet Alcohols from Exxon Chemical Company are produced domestically and offer an affordable route to better properties in your personal care formulations.

Call us to find out more about **EXXAL Guerbet Alcohols:**

EXXON CHEMICALS

EXXAL Alcohol Market Development, 713-870-6093
Exxon Chemical Company
P.O. Box 3272, Houston, TX 77253-3272

CIRCLE 33 ON READER SERVICE CARD

weaknesses—as well as strengths—of the ingredients supply business. Only a very few of the major chemical companies have elected to put much emphasis on supplying the cosmetics and toiletries industry—firms such as ICI, BASF, Hoechst, Akzo, and Henkel. Other major firms will have one or two products that might go into cosmetics, but it is not a major effort.

Next comes a second tier of medium-sized companies, whose sales to the cosmetics and toiletries industry are important, but usually in specific areas—Witco and Stepan, for example, with surfactants, National Starch and GAF with hair-care polymers, Croda with protein derivatives, and Lonza and Onyx with quaternary ammonium compounds for hair conditioning. Yet another tier consists of smaller companies that have found often quite profitable niches in supplying the industry—Reheis with antiperspirant actives, for example, or Grünau with protein hydrolysates.

Such small-niche marketers are probably even more important in Europe than in the U.S., believes ICI's Suter. One reason is the fragmentation of the cosmetics industry itself, which is still not yet conglomerated. "Our clientele is more fragmented. In the U.S., there are about 500 cosmetics makers. In Western Europe, if you take all the cottage ones, there are about 3000. That opens a niche for small suppliers, as well as the large ones. There are probably 30 major suppliers in Western Europe, compared with 10 in the U.S. Usually the local companies will have about 20 to 25% of the markets in their own locale. But the big companies don't have any more than 5 to 6% of the market, throughout the industry."

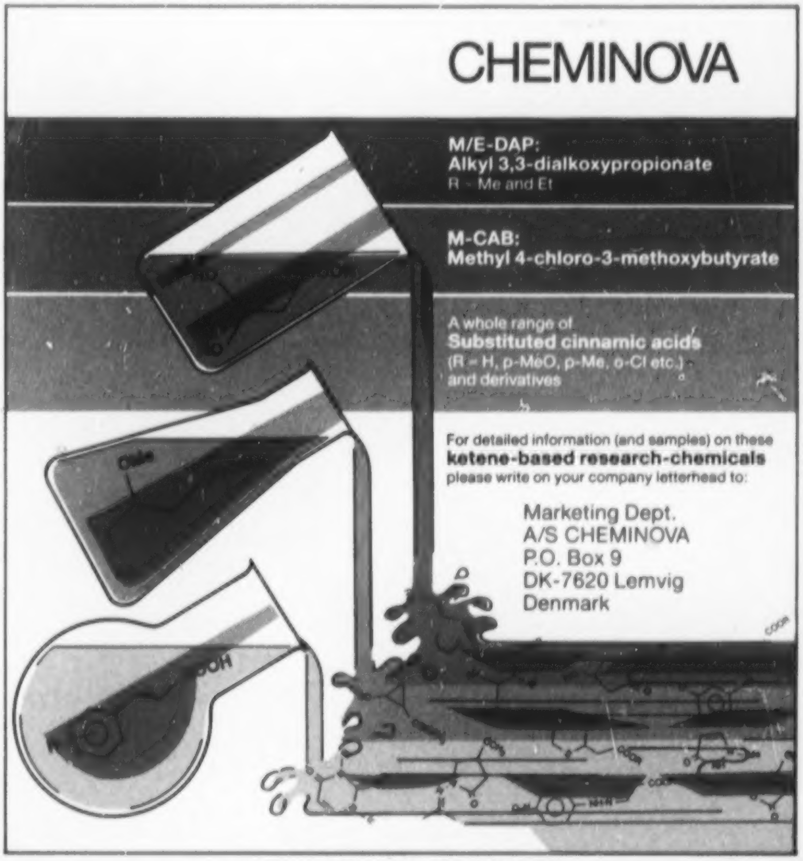
More suppliers are being bought up by larger ones. For example, Henkel in late 1986 bought Grünau, and at about the same time Union Carbide acquired specialty surfactants producer Amerchol. PPG Industries has jumped into the specialty surfactants business, acquiring Jordan Chemical and Mazer Chemicals; much of their activity is oriented toward the cosmetics and toiletries industry. Says Kline's Chandler: "There are very few pure opportunities left for raw material suppliers for cosmetics and toiletries. For a business whose overall growth hasn't been that exciting, however, a lot of people want to be in it."

Those small cosmetics firms that are left are that much more reliant on the product development talents of suppliers. Frequently, says ICI's Suter, the customers are "not very good chemists, although they may be good dermatologists. They come to us with a fancy oil, perhaps—mink oil, for example. Something difficult to formulate into something nice. We'll take it into our labs and formulate into, say, a soft cream, with a nice feel, and stable, capable of going from 50 to 60 °C on the beach, down to 0 °C in the hold of an airliner. They can then take the formulation, adjust it, add perfume, and do the packaging. That is usually their strength, the packaging—they are marketers, not chemists. They need us."

Technical service becomes all-important for suppliers, says Suter, who sees global experience important for being familiar with local raw materials, local processing conditions, and so on.

Akzo's Hogeweg would agree with that: Tech service is all. He feels it is particularly important for Akzo. "We are absolutely not integrated. We have no alcohols, no ethylene oxide. We have no large consumer outlet for captive use. We therefore try to give a little extra to all we do, a concept we call 'surfactant plus.' If someone wants a very narrow specification, for example, we can, we do, and we ask a few pennies more. We are less and less interested in supplying the detergent industry; they buy foam."

So if suppliers are giving more than foam to the cosmetics and toiletries industry, what sorts of things are they developing these days? Basically, ingredients that do things just a little bit better than before, or


CHEMINOVA

M/E-DAP:
Alkyl 3,3-dialkoxypropionate
R = Me and Et

M-CAB:
Methyl 4-chloro-3-methoxybutyrate

A whole range of
Substituted cinnamic acids
(R = H, p-MeO, p-Me, o-Cl etc.)
and derivatives

For detailed information (and samples) on these
ketene-based research-chemicals
please write on your company letterhead to:

Marketing Dept.
A/S CHEMINOVA
P.O. Box 9
DK-7620 Lemvig
Denmark

CIRCLE 28 ON READER SERVICE CARD

can add a certain plus to a customer's formulation.

Isethionates, for example, are one of the fastest-growing surfactant areas, playing on the idea of mild for synthetic-detergent toilet soap bars (syndets). Such syndets have been around for years: Lever Brothers' Dove and Procter & Gamble's Zest, for example. However, new suppliers are opening up the market, beyond those two giant soap producers.

PPG's Mazer Chemicals unit, for example, has a process for sodium cocoyl isethionate, as has Akzo, the only merchant supplier in Western Europe. Akzo's Hogeweg estimates that the market for syndet bars is 44 million lb a year in the U.S., but probably less than 1 million lb in Western Europe. Normally, he says, "a product is in one place, then within six months in another. Why not with syndets? In the U.S., syndet bars are just mild, sold in supermarkets. In Europe, they are sold for dermatological problem cases, sold in pharmacies. As long as we can't change that, the market will remain small. When we can sell in the supermarkets, the market will grow."

New uses for existing products are always important. For example, ICI Americas is finding new use for its cationic surfactants as effective active ingredients in deodorant products. Its Forestall surfactant neutralizes malodors by forming a complex with the volatile odor components, proving effective in tests in reducing underarm odors. Other potential odor-reducing applications are as a deodorizer for hair-care products and mouth rinses.

Work by Croda on keratin proteins that permanently bind to the hair during the permanent wave process means, in turn, permanent conditioning, says Kevin Gallagher, marketing manager. The permanent waving process depends upon breaking and reforming cystine bonds present in hair keratin. By applying its Kerasol proteins or Croquat WKP hydrolyzed keratin proteins to the hair during this process, he says, it is possible to reform cystine bonds not only within the hair but between the hair and kerasol, creating a permanent covalent bond.

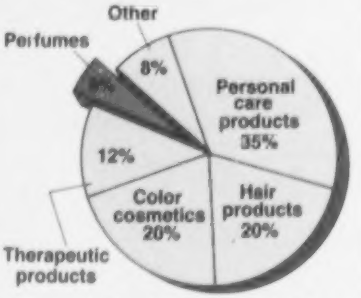
And National Starch has been adding to its families of cationic cellulose derivatives and amphoteric acrylic polymers for hair fixatives. These fixatives offer improved fixing ability while retaining good feel. Hair sprays, after years in the doldrums during the chlorofluorocarbon aerosol propellant controversy, have rebounded sharply over the past two years.

Many companies are expanding their capacities. For instance, Witco over the past two years has made a number of moves to strengthen its position in surfactants. In January, it acquired the West Coast surfactants manufacturing facility of Emery Chemicals, to get a foothold in

Everything.

*Trademark of The Dow Chemical Company

Perfumes are lagging in Japanese market



1987 retail sales = $13.8 billion

Source: Industry estimates

the fast-growing West Coast market. A new pilot plant and oxylation facility at Houston, which started up last year, increased capabilities to custom-make surfactants. That followed an expansion of esterification and sulfonation/sulfation facilities at Houston; and an expansion of the capacity for oleochemicals at its Humko Chemical Division's Memphis and Newark, N.J., facilities.

And what at least one Western European marketer has termed "huge sulfonation capacity" has begun operating in Eastern Europe, particularly in Poland and Hungary, and in the Middle East, including Iran and Jordan. There is a resulting rising overcapacity in surfactants, he frets. Some will replace markets historically served by Western Europe's exports, and some will come into Western Europe itself; other amounts will go into the domestic markets.

Poland, for example, is cited as the largest cosmetics manufacturing country of the East-bloc countries. Hungary is said to have the best chemical and pharmaceutical industries, but in cosmetics, the Poles are furthest ahead, even supplying the Soviet Union.

Suter notes that in supplying the cosmetics and toiletries industry, "The chemistry is not all that relevant. Terrible products don't exist any more—all products are within certain limits very good. So you need to differentiate by adding service—the reason you'd go to X rather than to Y."

After all, he adds, "In cosmetics, raw materials are only a very small percentage of the total cost. Why take the risk of changing suppliers if you are happy? What we need to do is reach a threshold of credibility with customers, so that they know we can solve their problems. This is usually the beginning of a very stable relationship. It is rare to change, especially if the product is successful."

But it all comes down, in the end, to the consumer. No matter all the claims by both cosmetics formulator and supplier alike, adds Suter's colleague Walters. "If it doesn't smell good, and go on good, and feel good, it just won't sell." ☐

From hair to eternity.

The Polyglycol Handbook

Dow polyglycols perform. As everything from consistency improvers in shampoos to humectants in archaeological preservatives. And beyond. Dow's unique alkoxylation capabilities give you the freedom to create new applications with custom ethylene oxide, propylene oxide, and butylene oxide derivatives. For an almost unlimited range of product possibilities. And now, everything you've always wanted to know about polyglycols has been condensed into one invaluable technical resource. The Dow Polyglycol Handbook. And a copy is yours when you call 1-800-258-CHEM. Or circle the reader service number below.

DOW
Polyglycols
The possibilities are endless.

CIRCLE 35 ON READER SERVICE CARD

APRIL 11, 1988

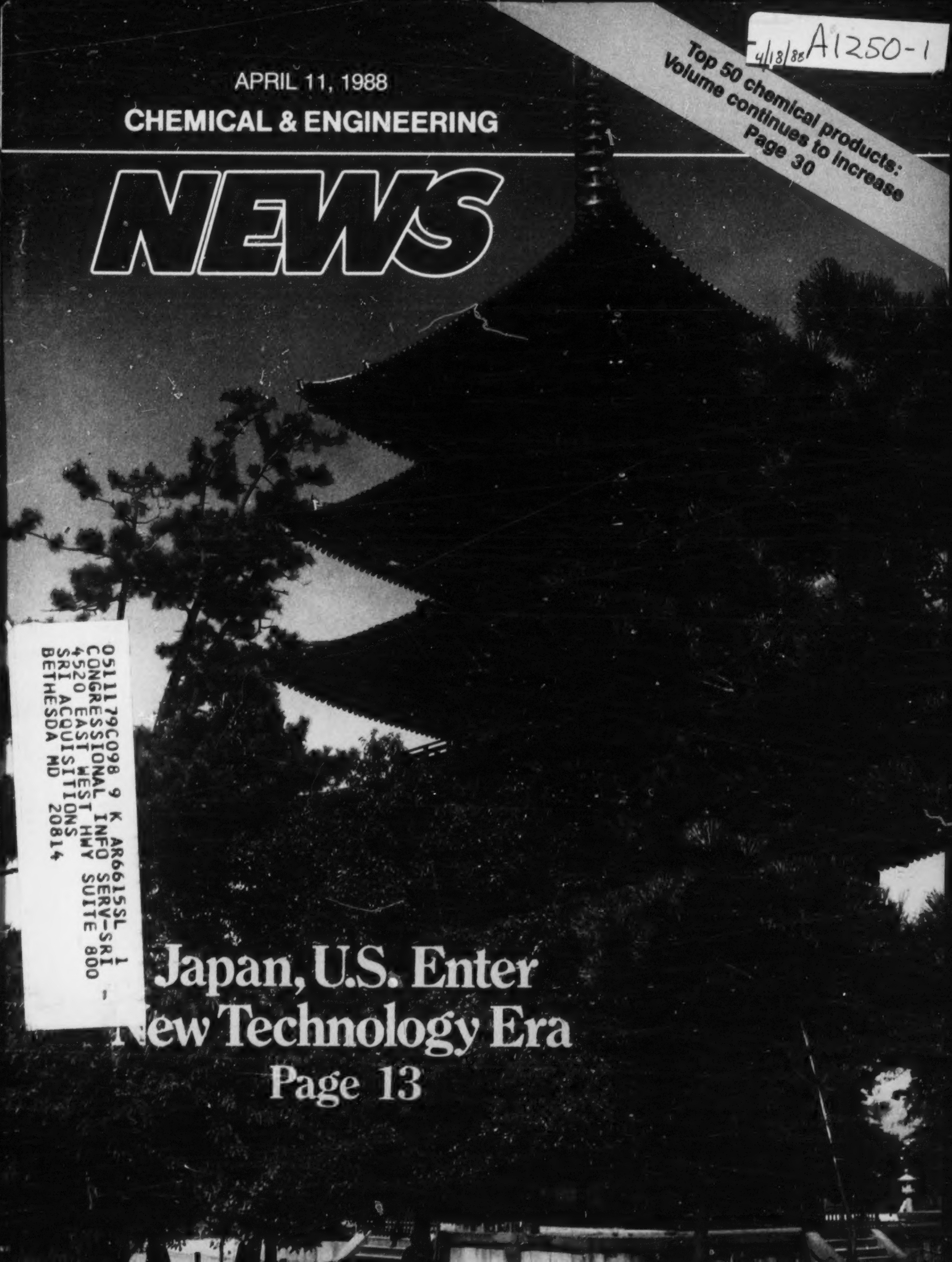
CHEMICAL & ENGINEERING

NEWS

4/18/88 A1250-1

Top 50 chemical products: Volume continues to increase

Page 30



0511179C098 9 K AR6615SL 1
CONGRESSIONAL INFO SERV-SRI -
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Japan, U.S. Enter New Technology Era

Page 13

CHEMICAL & ENGINEERING

NEWS

Volume 66, Number 15
CENEAR 66 (15) 1–78
ISSN 0009-2347

APRIL 11, 1988

News of the Week

- **House-Senate conferees have completed work on a massive trade bill, but President Reagan may veto the bill unless further changes are made in several provisions the Administration opposes. Page 6**
- **Union Carbide is expected to appeal last week's order by an Indian appeal judge that the company pay $192 million in interim relief to victims of the 1984 Bhopal gas leak. Page 7**
- **Monsanto's G. D. Searle unit has signed a collaborative R&D pact with China's state pharmaceutical administration. Page 7**
- **Monsanto and ICI have reached a settlement that protects Monsanto's glyphosate patents but gives ICI rights to market its own brand of glyphosate pesticide. Page 8**
- **U.S. and West European chemical industry associations have agreed on a set of trade policies they hope will be adopted at international trade talks in Geneva. Page 8**

Cover: Five-story pagoda at Kofukuji temple in Nara. Photo by C&EN's James H. Krieger

Letters 4

Concentrates

Business 23
Government 38
Science/Technology 44

The Departments

ACS News 56
Meetings 58
Newscripts 78

Business

Top 50 chemicals production got back on track in 1987, increasing 5.5% over 1986, partly on the strength of a surge in exports. **Page 30**

Output of polymers—plastics, synthetic fibers, and synthetic rubber—continued to climb last year, hitting a record 57 billion lb. **Page 33**

Avoid building plants leading to another round of overcapacity, petrochemical industry managers were warned at recent international conference in San Antonio. **Page 36**

Government

EPA has proposed new hazardous waste treatment rules that could have a significant financial impact on petroleum refineries and on steel and chlorine producers. **Page 39**

A study of Defense Department science and technology funding finds that basic research support has not kept up with inflation. **Page 43**

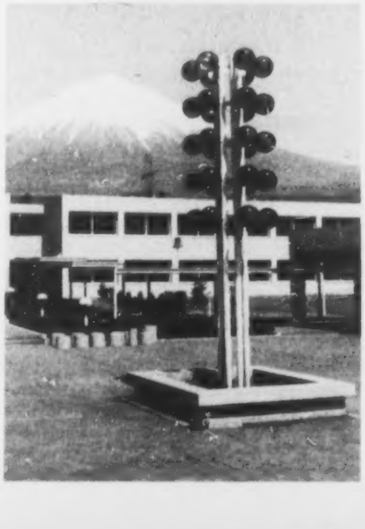
Science

Hundreds of Soviet Jewish scientists still seek exit visas, although the pace of emigration approvals has improved recently. **Page 45**

Twist-bent carbon-carbon sigma bonds do exist, according to extensive supercomputer calculations. **Page 50**

Technology

A device that concentrates solar energy into a very intense light beam has been developed at the University of Chicago. **Page 52**



News Focus

Despite some huge economic and cultural differences, the U.S. and Japan are increasingly sharing a common technological path, reflected in joint ventures, shared research, and technology exchanges. Page 13

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 77)

LETTERS

CHEMICAL SAFETY

Barium acetate precursor

SIR: We would like to bring to the attention of those currently involved in preparing high-T_c cuprate superconductors that a potentially hazardous situation exists when preparing these materials with a barium acetate precursor. Barium acetate is just one of several possible barium precursors for these materials.

A small explosion occurred in our laboratory during the initial heating of a small sample (3 g) of pellets in a tube furnace. The pellets consisted of a dry powder mixture of Y_2O_3, CuO, and $Ba(CH_3CO_2)_2$. Fortunately nobody was injured and no damage was done to the tube furnace. The quartz tube was destroyed. We attribute the explosion to the accumulation in the quartz tube of inflammable pyrolysis products of the barium acetate.

We have learned several lessons from this incident concerning the heating of samples with even small amounts of metal acetate precursors. First, pyrolysis products should not be allowed to accumulate. A sufficient flow of gas, preferably oxygen rich and in a large chamber, should be maintained at all times. Second, oxygen (or other gases) should not be reconnected to a hot furnace. Finally, safety should be considered in evaluating precursors for the new high-T_c superconductors.

Niles Fleischer
Department of Materials Research
Weizmann Institute of Science
Rehovot, Israel

Polonium-210 contamination

SIR: Air ionization devices that contain radioactive polonium-210 are in common use in industry where static electricity must be discharged. Recently, a significant fraction of the 20,000 devices manufactured by 3M have been found to be leaking polonium-210 (C&EN, Feb. 22, page 15).

These devices contain polonium-210 microencapsulated on 35 μm-diameter ceramic beads, which are cemented onto a surface. The intense alpha radiation field ionizes air out to the maximum range of the alpha particles in air—about 5 cm. When they leak, the microcapsules break loose and contaminate the surrounding workplace.

The potential health effects from contamination by this alpha-emitting radionuclide are modulated by several factors. Since alpha radiation cannot penetrate the dead layer of skin on the body, the only hazard is from inhalation or ingestion of the polonium-210. However, since the settling velocity of a 35 μm-particle is about 5 cm per second, it quickly falls to the floor and inhalation is unlikely. Also, since the microcapsules are insoluble, ingested material would pass rapidly through the gastrointestinal tract. That is the good news.

The bad news is that polonium-210 has an oral radiotoxicity similar to that of plutonium. The International Commission on Radiological Protection (ICRP Publication 30) gives the annual limit of intake (ALI) for ingestion of polonium-210 as 3 microcuries, while the value for plutonium-239 is 6 microcuries. Thus, a typical static eliminator containing 40 millicuries equates to over 10,000 oral doses equal to the ALI.

Chemists should be aware of these facts in advising their management about the consequences of polonium-210 contamination from leaking static eliminators.

Wesley R. Van Pelt
President, Wesley R. Van Pelt
Associates Inc.
Paramus, N.J.

Darwin's warm little pond

SIR: I was surprised by Bernard Erlanger's assertion (C&EN, Jan. 25, page 3) that Charles Darwin's well-known "warm little pond" statement was intended only as an expression of contempt for the idea of spontaneous generation and was without meaning in regard to the origin of life.

My surprise came from having seen this statement quoted so often as an early, if not the earliest, expression of the contemporary chemical evolution hypothesis. Darwin's statement is largely known as a result of its appearance in a footnote appended by Francis Darwin to a letter written by his father to J. D. Hooker in 1863 (see F. Darwin's "Life and Letters of Charles Darwin"). In this letter the elder Darwin is clearly critical of spontaneous generation; he also states his opinion, as he frequently did, that the question of the origin of life was beyond the scope of latter 19th century science.

However, it is not so clear that Francis Darwin meant to reinforce his father's position on spontaneous generation by footnoting the warm-little-pond statement as Erlanger believes. There are many other statements of Charles Darwin that could have been cited to buttress this point more clearly and force-

U.S., Japan Approach New Era In Science and Technology Relations

Although difficulties and prejudices still abound, a more integrated future for the two nations lies ahead through joint industrial ventures, shared research, and technology exchanges

Wil Lepkowski, C&EN Washington

Despite feverish economic strife and vast cultural gaps, Japan and the U.S. are finding themselves bound on a joint course into a technological future. Conflicts may be hiding the commonalities, but most Americans who have visited Japan and worked within the Japanese technical establishment come away with the feeling that the two countries now share a common path.

Through an elaborate effort to reshape its science and technology policy, Japan is in the midst of a growing technical drive into technologies based on the information sciences and advanced materials fields. The specifics are still being worked out, but every major science policy document, such as Japan's latest White Paper on Science and Technology, underscores Japan's new international role.

For three decades Japan has been a taker in the global technology markets—selling products based on acquired Western know-how while closing its borders to imports. Now it says it wants to return the favors it received while becoming a global powerhouse in basic research.

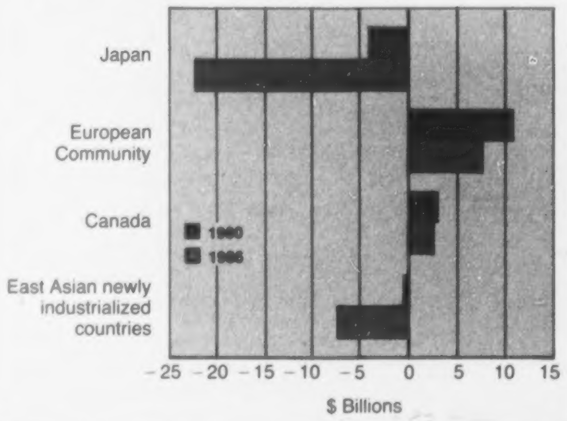
According to Sen. John D. Rockefeller IV (D.-W.Va.), the Japanese ought to start realizing anew that they owe the U.S. a tremendous debt of thanks. Rockefeller majored in Far Eastern studies in college, lived in Japan for several years, has fostered through his activities and Rockefeller family philanthropy Japanese-American understanding over the years, and has sponsored legislation in the Senate aimed at improving Japan-U.S. technical relations.

"We rebuilt Japan as surely as we rebuilt Europe through the Marshall Plan," he says. "If anything, what was accomplished in Japan was even more miraculous. With no democratic traditions, a modern, democratic, free industrial giant emerged."

But Japan took too much an advantage of its growth, Rockefeller believes. "If every nation behaved as Japan has—maximizing exports, minimizing imports, practicing what amounts to mercantilism—the international system would have collapsed years ago." Now, Rockefeller adds, the situation has gotten so economically out of balance that "economic growth in the U.S. now depends on Japanese willingness to lend us tens of billions of dollars yearly to finance our budget deficit and overconsumption."

Japan has begun taking steps, as outlined in its landmark Maekawa report on restructuring the economy. The U.S., with a trade deficit with Japan last year of $60 billion, naturally wants more than words of intention from the Japanese. Although Japan already has dropped one trade barrier after another—a big breakthrough was Japan's agreement two weeks ago to open up its big construction projects to American bidders—the pressure is on the Japanese to lower other barriers that keep American consumer items

U.S.'s largest trade deficit in high-tech products is with Japan



priced prohibitively high to Japanese. Japan has established policies to do that.

Japan, meanwhile, has never been able to abandon its feeling of dependence on the U.S. But it doesn't quite trust America either. Its fear is that an impulsive U.S. will abandon its "protection" of what is to Japanese perceptions a weak, fragile, and small island nation. In contrast, disturbing reports reach the public of renewed Japanese arrogance toward the West's inability to keep pace technologically with Japan.

The reality is that the open, blunt Americans and the hierarchical Japanese with their intricately codified nonverbal mannerisms have never known one another very well. And they still don't. What they have, though, are the common language needed in the doing of science and technology and a certain common purpose as world leaders among the democracies.

Japan's Prime Minister Noboru Takeshita talks of a new sense of furusato, or "hometown," policy of enriching the domestic economy and social spheres and in the process widening the volume of imports. Japan's new economic "dream" includes big public works programs, such as the vision of a new capital to be built some distance from super-expensive and overcrowded Tokyo. Japan's fiscal 1988 budget calls for $54 billion worth of public works projects. Takeshita's major priority is to push through a tax policy that can pay for the internal changes he has in mind.

Although the new policy may not open Japan's doors to American high-tech products immediately, it already has for such products as California wines. U.S. high-tech companies, such as those producing value-added specialty chemicals, are just beginning to study what an upgraded Japanese consumer economy will mean for them.

The fact of Japan and the U.S. as scientific and technological partners has been played down against the tense political rhetoric of today. The spectacle of U.S. congressmen battering with sledge hammers a Toyota automobile in front of the U.S. Capitol is by now the public's stereotypical image of the state of relations. And Toshiba Machine's sale of fabrication technology to the Soviet Union for the rapid manufacture of submarine propellers is seen in the U.S. as a modern form of Japanese treachery. More recently fears have grown that the Japanese are purchasing America's assets through investments in U.S. corporations and real estate.

Japan spends less than half what U.S. does on R&D

	U.S.	Japan
R&D expenditures	$100.4 billion (1986)	$40.0 billion (1985)
As % of GNP	2.7%	2.8%
Nondefense as % of GNP	1.8%	2.8%
% financed by industry	50% (1985)	67% (1985)
Basic research as % of total R&D	12% (1986)	13% (1985)
Nonacademic scientists and engineers	2.844 million male 334,000 female	1.444 million male 69,800 female
% foreign students science	18.2% (1984–85)	0.7% (1983–84)
% foreign students engineering	21.7% (1984–85)	1.1% (1983–84)
Patents granted in U.S.	47,077 (1970)	2,625 (1970)
	46,715 (1975)	6,352 (1975)
	37,356 (1980)	7,124 (1980)
	33,896 (1983)	8,793 (1983)
	38,124 (1986)	13,209 (1986)

Source: National Science Foundation

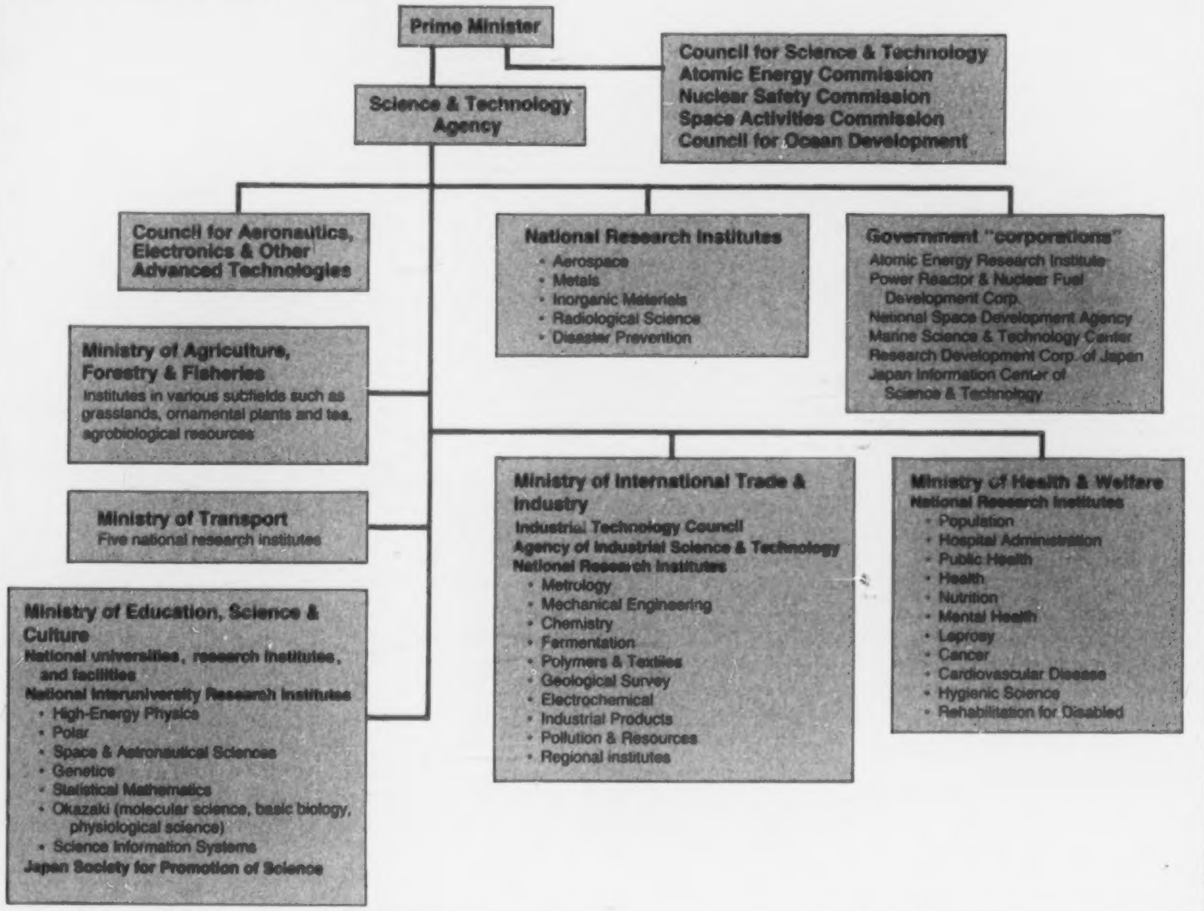
"I see the relationship with Japan becoming worse," warns Michael B. Smith, deputy U.S. trade representative in a recent interview with the *Journal of Commerce* newspaper. "As they grow more and more powerful, they're going to be less and less willing to make deals."

Although the Japanese profusely apologized for the Toshiba incident, they regard the overall mood in the U.S. as unrealistic Japan-bashing and are bothered by it. They say a lot of the accusations are true, but add that most of them are unfair, a reflection of U.S. deficiencies, and they stress that in any case they are changing. The situation between the two countries is such a complex mixture of fact, fancy, and sheer cultural misperceptions that issues have to be dissected carefully to assess the true nature of the relationship. Outlining the "togetherness" aspect seems long overdue.

The signs of this togetherness include:

- The willingness of the Japanese to begin putting up money in international research ventures, such as in their revamped Human Frontiers Program that would make a global assault on the mysteries of human biology, from brain function to molecular immunology.
- The extensive network of research, development, and marketing collaborations between corporations in the two countries. Patent litigation is picking up, too, but this phenomenon doesn't contradict the intermingling of interests.
- Growing interest among Americans in understanding the Japanese language and culture. More than 20 Japan-America societies exist in the U.S., with growing membership and active programs.
- Spirited competition among the states to attract Japanese manufacturing companies. States with full-time offices in Japan now number 36.
- Frequency of meetings and conferences on the subject of Japan-U.S. relations in technology and science.
- A soaring interest among American corporations in learning more about how Japanese companies manage technology and the ways they have redefined the meaning of "basic research." Dow Chemical has stationed seven persons in its technology office in Tokyo, strictly to monitor Japanese advances and make connections with Japan's innovators.
- Enormous American dependence on the Japanese for advanced military technology. This is naturally a source of conflict and embarrassment to the U.S. The new FSX fighter would contain almost all Japanese

Japan's science and technology structure


Prime Minister
Science & Technology Agency
Council for Science & Technology
Atomic Energy Commission
Nuclear Safety Commission
Space Activities Commission
Council for Ocean Development
Council for Aeronautics, Electronics & Other Advanced Technologies
National Research Institutes
• Aerospace
• Metals
• Inorganic Materials
• Radiological Science
• Disaster Prevention
Government "corporations"
Atomic Energy Research Institute
Power Reactor & Nuclear Fuel Development Corp.
National Space Development Agency
Marine Science & Technology Center
Research Development Corp. of Japan
Japan Information Center of Science & Technology
Ministry of Agriculture, Forestry & Fisheries
Institutes in various subfields such as grasslands, ornamental plants and tea, agrobiological resources
Ministry of Transport
Five national research institutes
Ministry of Education, Science & Culture
National universities, research institutes, and facilities
National Interuniversity Research Institutes
• High-Energy Physics
• Polar
• Space & Astronautical Sciences
• Genetics
• Statistical Mathematics
• Okazaki (molecular science, basic biology, physiological science)
• Science Information Systems
Japan Society for Promotion of Science
Ministry of International Trade & Industry
Industrial Technology Council
Agency of Industrial Science & Technology
National Research Institutes
• Metrology
• Mechanical Engineering
• Chemistry
• Fermentation
• Polymers & Textiles
• Geological Survey
• Electrochemical
• Industrial Products
• Pollution & Resources
• Regional institutes
Ministry of Health & Welfare
National Research Institutes
• Population
• Hospital Administration
• Public Health
• Health
• Nutrition
• Mental Health
• Leprosy
• Cancer
• Cardiovascular Disease
• Hygienic Science
• Rehabilitation for Disabled

components. But the U.S., fearing further trade imbalance, won't let the Japanese build it.

In short, though tensions exist and in some areas will probably get even worse, the U.S. and Japan already globally oversee a complementary technological empire, or "technopolis" as termed by Dataquest Semiconductor's Sheridan Tatsumo.

The process of Japanization has been, of course, accelerating over the past 20 years in the U.S., with the influx of Japanese transistor radios, textiles, and steel, then—in a jump to mid- to high tech—cameras, automobiles, video and stereo equipment, semiconductors, and personal computers. The blessings to Americans of that "invasion" were naturally mixed. Consumers liked products of high quality, elegant design, and low price. At the same time, traders and economists became terrified over the political and economic implications. In the high-tech area, only chemicals seemed to be maintaining a U.S. advantage, with a consistent 2.5:1 ratio of exports over imports. Meanwhile, Japan was getting rich.

Some economists feel that Japan will become so powerful that the world will be forced to divide itself into three large, exclusive trading blocs consisting of the Americas, Europe, and Japan. Others, such as Japanese technology expert Ellen L. Frost of Westinghouse Corp. and author of the book, "For Richer, For Poorer—the New U.S.-Japan Relationship," believes such projections are now simply passé. She believes the two financial and commercial systems are so intertwined that such a phenomenon is practically impossible.

One factor in favor of the "new alliance" is that Japan is determined never again to be an aggressive military power. Its future lies instead in international cooperation. Its constitution forbids militarizing, Japan wants no part of it, the world—the Soviet Union and China especially—won't tolerate it. In fact, some historians have said that the Japanese felt inwardly relieved to have lost World War II because defeat, though hideously punctuated by the atomic explosions over Hiroshima and Nagasaki, rid Japan once and for all of its expansionistic warlord tradition. Shoguns and their loyal samurais take a new form in Japan's pursuit of its new economic dream as the captains and sergeants of industry and technology.

And they're so good at it that they give people chills.

"Every time I've gone with a group to Japan over the past two or three years to visit research leaders, laboratories, and universities," observes materials scientist Rustum Roy of Pennsylvania State University, "we come out of the rooms saying, 'My God, how are we ever going to catch up with them in R&D?' As of now, their research in the field of materials is head and shoulders above anything we are doing. The R&D plants they are installing today have no equivalent in this country."

Roy believes that once the Japanese switch fully into gear in superconductivity R&D, the U.S. will hardly stand a chance to compete head to head. "To think there is any U.S. company that can compete with the Toshibas, Sumitomos, Mitsubishis, and Kyoceras in this field in making commercial products is ridiculous. No one here would have the strength to stay in the business long enough to sustain the up-front money. If any company dared spend the amount of money needed, it would be the victim of a corporate takeover. In fact, if you ask me, it is Wall Street that's the villain here. It's the enemy of American R&D."

There are dozens of reasons, all set down in current writings, why the Japanese are so good. Individuals find their identities in groups. They are an island nation bent on survival. Workers give total loyalty to their companies. Salaries of corporate officers are nowhere near those of their counterparts in the U.S. Decisions are made by consensus, from the bottom up. The Japanese character pays passionate attention to detail. Engineers push design to the limits of efficiency, elegance, and miniaturization. Japanese plainly want their products to be the best anyone can make. They know how to manage technology. Their companies know how to cooperate in sharing technology with one another. Yet they compete for markets with no holds barred.

That combination is too little understood, says political scientist Richard Samuels, director of Massachusetts Institute of Technology's highly touted Japan program, which gives science and engineering students Japanese language training and the opportunity to spend up to a year in Japanese laboratories.

Says Samuels, "The mystery is how they are able to defy economic theory. The Japanese companies have found a way to cooperate in research while being wildly competitive with each other."

Herbert Fusfeld, director of the Center for Science & Technology Policy at Rensselaer Institute of Technology, says Japanese engineers are more versatile than their American counterparts. "The Japanese stay in one company and move there from function to function. In U.S. companies you have that traditional division between product and process. U.S. engineers don't tend to move from one group to another, and this gives the Japanese a real advantage. Everyone is doing everyone else's job over time."

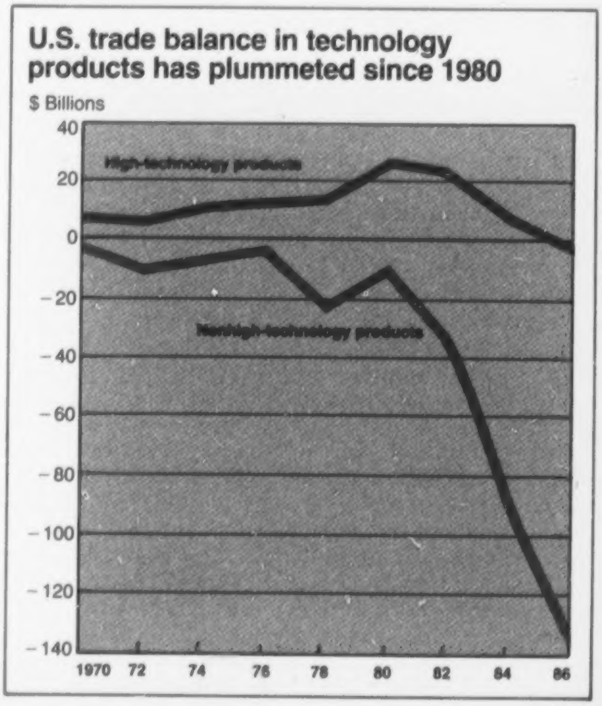
Justin Bloom, president of Technology International Inc., who for years served as science adviser at the U.S. embassy in Tokyo, has taken special interest in the Japanese practice of consensus building.

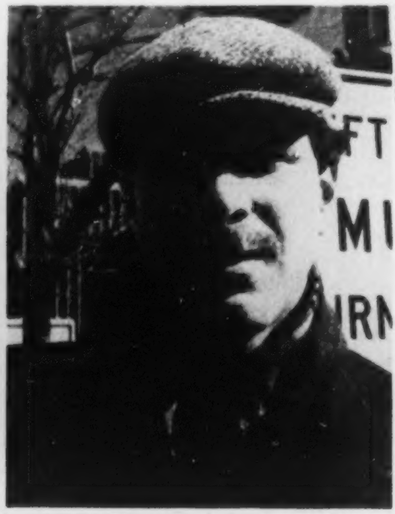
"One thing most Americans can't comprehend about the Japanese is that consensus building is not a top-down process for them," he explains. "They call it a bottom-up process. The key decision-making level in Japan is in what they call the kacho—typically five to 10 lower-level management people who act as a filter in bringing information to the top man. If those young guys—30 to 40 years old—don't think the idea is good, it never sees the light of day. The people upstairs don't get involved in the sordid details."

National Science Foundation policy analyst Robert S. Cutler, who recently spent a year studying technology transfer processes in Japan as a Fulbright fellow, says a further magic lies in the "small country" atmosphere in Japan.

"Some people notice that Japanese companies seem to sell similar products," he says. "It looks a lot like they might be collaborating on the designs and specs. That's because high-tech Japan is a small country and all the engineers know each other. When one company starts something, even the company presidents call each other to discuss it. And Japanese companies don't suffer from the 'not invented here' syndrome that so hobbles U.S. innovation. Instead, they are eager to please their customers and would rather get their people involved in making something better for the marketplace."

Another quality is patience on the part of the institutions that fund industrial research in Japan. For example, Hitachi, in its drive to develop advanced software, has accumulated a reservoir of $4 billion from its parent banks to fund the R&D work needed


U.S. trade balance in technology products has plummeted since 1980



C&EN staff photos

Rockefeller (left): Japan took too much advantage of its growth. Frost (middle): three-bloc idea now passé. Samuels: how firms defy economic theory is mystery

to make the leap to the next generation of that technological art form.

According to Sheridan Tatsuno, senior industry analyst for Dataquest's Semiconductor Industry Service, Japanese companies have resigned themselves to losses "over the next five years" as they regroup toward the creation of Japan's "technopolis strategy for the 21st century." Tatsuno made his remarks last fall at a symposium on U.S.-Japan technology exchange sponsored by the Japan-America Society of Washington, D.C. As a reflection of the new awareness of technological Japan, the society is reorienting much of its program to serving corporate interests. The symposium's papers have just been published.

At the same symposium, Gerald Dineen, vice president, science and technology, for Honeywell, offered his assessments of Japanese incentives for innovation. "We emphasize the movement and manipulation of numbers on a ledger," he says. "Japan emphasizes the movement and manipulation of products. Japan's unique capital markets allow corporate senior management to make longer-term investment decisions. Japanese corporations are highly leveraged; hostile takeovers are almost unheard of in Japan; and Japanese investors take the long view and, in many cases, favor reinvestment of capital over increased dividends." He didn't add, in this respect, that workers hold a substantial amount of corporate stock in Japan.

Most observers believe that the Japanese have the most catching up to do in basic science. They apparently know it, and a recent report on U.S. and Japanese education systems confirmed it. One reason why American technical scholars make so little use of Japanese literature is that their bibliographies contain predominantly U.S. and West European citations.

The problem of Japanese scientific creativity was underscored by MIT immunologist Susumu Tonegawa, who shared the Nobel Prize in Medicine last year. Tonegawa openly criticized the Japanese research system for stressing conformity at the expense of the imaginative boldness that comes from individuality in U.S. and West European research. He said he had to come to the U.S. to give his mind full flower and that Japan, unless it changes, would continue to be handicapped with respect to creative science.

Japanese native Leo Esaki of IBM, winner of the 1973 Nobel Prize in Physics for his discovery of the tunnel diode, has more specific things to say about the basic research mentality in Japan.

"A traditional value system that is as widespread as in Japan is not easily or quickly changed. . . . Japan has produced no great philosophers. Novelists and poets, yes—but generally the Japanese are uncomfortable with abstract concepts. Their instincts are more emotional than philosophical; they try to capture the world by intuition rather than by logic.

"It is true that in many cases group-oriented societies work very nicely. They can be wonderful production factories. . . . But the price you pay in such a controlled environment is a lack of creativity. Since scientific creativity is the most important element in basic research, it comes as no surprise that Japan lags behind. This is not because applied research has received undue emphasis—it is simply that basic research cannot be done. The Ministry of Education thinks that if you have plenty of money, you can do what you like. The Japanese do not like to hear me say this, but money is not enough. If you are not your own master, if you do not have your own soul, you will be an object rather than a creative subject."

Roy has a contradictory view. He thinks the term basic research is going to acquire a new 21st century meaning under Japanese influence. "We are in a new era now," says Roy, "where technology is driving science. Most of the Nobel Prizes now are going to discoveries that are either based on technology or embody it. I think it was a basic research development of the highest magnitude that Japan mastered the transition process from science to technology. Japanese creativity is different. We shouldn't judge them on outmoded standards. There is enough 'basic research' on the shelf to keep Japan going for the next 50 years."

Samuels adds that Japan has always been an adaptable society and it will therefore find a way to change its educational structure to promote individual creativity. Experimental schools already exist, he says, for that purpose.

Over the past year, the word, "symmetrical" has come into vogue in scientific relations between the two countries. A meeting in Hawaii next month between Japanese and U.S. scientists and industrialists will be defining the word in terms of technical exchange. The gathering is being sponsored by the National Academy of Sciences and the National Academy of Engineering. It will offer each side a chance to discuss most of the significant cultural differences between the two countries.

Many such meetings have been occurring in the past few months and practically everyone involved thinks they're needed.

Vastly different notions of symmetry had been hampering the negotiations between the U.S. and Japan over the renewal of a Presidential-level scientific exchange agreement in process for about a year. But U.S. negotiators, led by White House science adviser William R. Graham, decided it was time to redefine the framework of U.S.-Japan relations in science and technology and set about reworking the agreement. After six meetings, final wording was reached on March 30 and President Reagan and Prime Minister Takeshita are expected to sign the agreement by June.

The specifics will not be released until then, say State Department sources. But the Japanese agreed to admit more American researchers to their university and government laboratories and to help out in language training. Specific areas of collaboration were agreed upon in all the areas of research crucial to both countries—from biotechnology to advanced software. American negotiators hoped to jimmy open Japan's dynamic industrial laboratories for exchange, but such a practice was left up to the companies to work out individually.

What really hampered the talks was American insistence that intellectual property and national security practices be better spelled out. In the end it was decided, not surprisingly, that rights to inventions would follow the rules of the host country. In essence, says a government source, "if you're doing a joint project, you divvy up the patent rights."

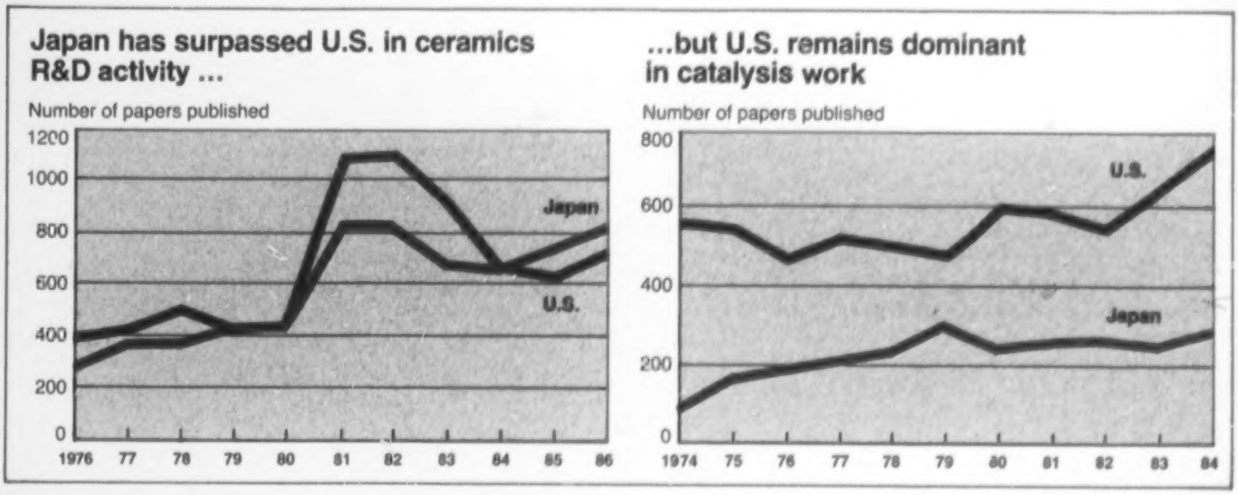
The basic principle was that the widest possible distribution of information and equipment be the practice, though subject to export control laws of each country.

What was groundbreaking about the agreement was not so much its components but the fact that the Japanese and Americans were able to agree on a written framework for all future government-sponsored relations.

What the pressure by Graham has done, according to Charles T. Owens, head of the National Science Foundation's international division, is to spur the Japanese to change their habits. Although the Japanese are not willing to be bullied, they are, Owens says, "scouring the landscape for opportunities to make us feel better about the science and technology relationship and where it is going."

Owens spent three years as head of NSF's Tokyo office. He is currently helping administer the recently announced $4.4 million grant by the Japanse to NSF for supporting scientists wishing to do research in Japan. He also issues a series of translations of Japanese science policy developments. The series is the most complete source of policy-related science and technology developments in Japan's national laboratories, universities, and industry.

Fusfeld (left): Japanese engineers are more versatile than U.S. counterparts. Bloom (above): consensus building a bottom-up process. Cutler: further magic is small country atmosphere


Japan has surpassed U.S. in ceramics R&D activity ...

...but U.S. remains dominant in catalysis work

A countertrend to the cooperative mood in Washington is a continuously rising protective—as opposed to protectionist—attitude by U.S. government officials toward American science and technology. Although corporations are collaborating on one level, the government is taking pains to restrict information to Japanese who visit and work in government laboratories, pending assurance that American visitors are given reasonably free access to Japanese research. The provisions will be spelled out in the *Federal Register* sometime this month.

Thus, because of the intense competition in technology, government-sponsored research is coming to be seen as a commodity with a price and a value. And this trend cannot but intensify.

What may not be intensifying but is at least increasing is the interest by American companies in Japanese technology. Use of Japanese literature has not taken off yet, by any means, with University Microfilms recently having ended its hopes of marketing a translation service of Japanese journals. Business interest simply wasn't that high.

The key component in technology transfer, as Cutler has pointed out in his study of university-industry technology transfer in both countries, is person-to-person interaction. Dow Chemical, which operates a seven-person technology office in Tokyo—the largest such operation among chemical companies in Japan—finds the people it wants to know by first scanning Japanese patents.

Up until last month, the office was run by Mark Kelly, who is now retired and living in Santa Fe, N.M. The Dow operation is small compared with counterparts in the electronics field. However, the big difference is that Dow seeks out cooperative ventures with the Japanese. The other companies run, as he puts it, "G-2 operations," World War II parlance for clandestine work designed to outwit an adversary.

Patents Dow concentrates on, says Kelly, involve mainly biotechnology and pharmaceuticals, engineering plastics, membranes for separation processes, and fine ceramics. These are fields Dow is trying to develop a future in to go along with such primary areas as drugs, agricultural chemicals, epoxy resins, urethane chemicals, and polystyrene foams in which Dow already has a strong market position there.

"The point is to target technologies we want access to," he says, "and places we want to establish relations with. These mainly involve 140 chemical, rubber, and steel companies, along with university and government research labs. We think we've had good success with all of them."

Once a target for a new relationship is selected, contact is made with the board of directors of the Japanese facility to arrange a visit. Kelly would usually present a basic slide show about Dow and its global interests. The activity has led in the past three years to about 60 visits by Dow people to Japan, and around 75 visits to Dow by Japanese industrialists. Kelly says every manner of relationship is discussed, from joint ventures to licensing of technology. About a dozen formal technology exchanges have been worked out since the office opened in 1984.

Kelly says it isn't wise to publicize Dow's office in Japan, where modesty is a highly valued virtue. "It's not how you do business there," he says. He adds that the Japanese chemical industry is much more cooperative than either the automotive or electronics industries. "I guess it's because chemical companies all over the world have to compete with as well as sell to one another."

American companies have had a presence in Japan since the Meiji Restoration of 1868 when Shogun rule during the 200-year Tokugawa period came to an end and Japan decided to become an international nation.

Eastman Kodak, for example, set up shop in 1869, and despite its embarrassing loss of the 35-mm camera market to the Japanese, remains one of the biggest American profit-makers there through the sale of sophisticated photographic equipment in the medical and scientific fields. It has learned to sell, trade, borrow, and license with the Japanese, and now is in the midst of relearning consumer camera technology from the Japanese.

Those companies with a long-time presence in Japan seem to have the edge in whatever patterns take form. But other American firms have a lot to learn, as much about Japan as about what they should be about.

Says Westinghouse's Ellen Frost, "American companies are too wrapped up in short-term mentality and perceptions. Industry is not at all willing to hire the people and put up the money to understand Japan. Few U.S. companies have a 10- to 15-year strategic plan that corresponds in any way to what the Japanese do. If you lift the lid off, though, you see a lot of joint ventures and cross-licensing. The U.S. still has a 3-to-1 advantage in cross-licensing. So there's a lot of irony in the situation."

The extent to which U.S. and Japanese high-tech firms are collaborating is surprising once that "lid" is lifted. The most complete study of those relations was recently published by Fusfeld's RPI center in a project directed by Lois Peters entitled "Technical Network Between U.S. and Japanese Industry."

Peters' report—234 pages rich in detail and insight—covers various types of alliances involving robotics, machinery and machine tools, energy, information processing and electronics, chemicals, pharmaceuticals and biotechnology, and metals.

How U.S. and Japan rate in key research areas

Substance and materials

U.S. leads in . . .

- Performance under extreme conditions
- Surface boundaries
- Theoretical design techniques
- Theories of reaction for syntheses
- Compounding materials

Japan leads in none of the areas designated

Electronics

U.S. leads in . . .

- Molecular electronics
- Bio-electronics
- Artificial intelligence software

Japan leads in . . .

- Optoelectronics

Life sciences

U.S. leads in . . .

- Design and synthesis of functional proteins
- Micromanipulation of DNA and chromosomes
- Cell manipulation
- Brain mechanism studies
- Immunology

Japan leads in none of the areas designated

Production and processing

U.S. leads in . . .

- Computer software

Japan leads in . . .

- Robotics
- Very large scale integrated circuits
- High-precision work

Both are about even in . . .

- Computer hardware

Source: Japanese government surveys

A fascinating portrayal in her report is that of Motorola, one of the more successful American "competitors" with the Japanese. Motorola's strategy is to have its fingers in every important pie in electronics. It is involved in the Defense Department's multi-industry very high speed integrated circuit program, with the Microelectronics and Computer Technology consortium in Austin, Tex., with Stanford University's university-industry computer-information sciences program, and the Semiconductor Research Corp. in North Carolina.

That is only the beginning. Motorola also has alliances with Hitachi and Toshiba through MITI's national R&D programs, and with Europe's government-university-industry ESPIRIT program that has hopes of giving Europe parity with Japan and the U.S. in electronics and information sciences. In short, Motorola is the prototypical component of that "technopolis" Tatsumo says is emerging.

The phenomenon scrambles the meaning of competing. "Who is going to compete with whom?" Peters asks. "Is there such a thing as a technological winner? It is most likely that growing international technical cooperation will result in even more rapid diffusion of technology, leaving firms to compete on an equal technological base with other factors becoming increasingly important.

"The popular concept of U.S. and Japan competing as countries is more pragmatically a complex mix of competition among individual companies using technology from others, or competitions among binational teams. Technical alliances can strengthen corporate actions even as they confuse national policies."

Ohio is a case in point. The state, with 94 Japanese companies now located there, is celebrating an enormous expansion of industrial ties with Japan. Most recently, Honda Motor Co. announced plans to break ground for a new $380 million assembly plant adjoining the earlier plant built in 1979 near Marysville. Construction began on March 21. Ohio has nothing but praise for the marriage of its labor pool with Japanese technology and management.

And so do Ohio's bankers, who see no danger from any Japanese takeover of assets in their state. During a conference last fall held by the Japan-Midwest Association in Columbus, Jerry V. Jarrett, chairman of Ameritrust Corp. of Ohio, said he was looking ahead to further "interconnecting webs of productive relationships" between Japan and the states.

After first reviewing the acknowledged problems of U.S. deficits and Japanese insularity, he said the world would never be the same again. "We stand today on the threshold of an exciting new period of international alliances of all kinds, from licensing and joint ventures to full-scale mergers and acquisitions."

"Companies everywhere," he said, "are experimenting with new ways to expand their global reach in the most efficient ways possible. With modern communi-

Sampling of collaborations of U.S. companies with Japanese firms

CHEMICALS

Hercules/Sumitomo Chemical: Sumitomo licenses conductive elastomer technology for keyboard data entries.

Diamond Shamrock/Showa Denko: joint venture to produce agricultural chemical and veterinary drugs.

Du Pont/Nissan Chemical Industries: Du Pont uses Nissan's high-density polyethylene technology to develop third-generation HDPE resin.

Olin/Kanegafuchi Chemical Industry: Olin licenses ion exchange caustic soda technology.

Air Products & Chemicals/Daido Sanso: Daido serves Air Products markets in Pacific region.

W. R. Grace/MTP Kasei: joint venture to produce and market variety of chemicals, including soundproof materials, rust preventives, and adhesives.

Celanese/Nippon Shokubai: joint venture to develop synthesis-based processes for petrochemicals.

PHARMACEUTICALS/BIOTECHNOLOGY

Bristol-Myers/Kyowa Hakko: Bristol-Myers licenses rights to develop and sell anticancer drug mitomycin C.

Abbott/Hokuriky Seiyaku: Abbott licenses bronchodilator, Bremax.

Merck/Yamanouchi Pharmaceutical: Merck licenses urinary infection antibacterial Noroxin.

Merck/Torii & Co.: Merck acquires majority interest.

Genentech/Kyowa Hakko and Mitsubishi Chemical Industries: joint venture to produce tissue plasminogen activator using Genentech methods; Japanese firms to provide financing and do clinical trials.

Schering-Plough/Yamanouchi Pharmaceutical: Yamanouchi licenses α-interferon manufacturing technology.

Genex/Green Cross: exclusive 15-year license for Green Cross to market Genex's human serum albumin from microbial strain.

Genetic Systems/Daiichi Pure: exclusive rights for Daiichi to sell for research only certain Genetic Systems monoclonal antibodies.

Source: Rensselaer Polytechnic Institute

cations and international markets, technology has a way of diffusing itself around the world like salt in water. Trading partners like the U.S. and Japan have to live with each other with a degree of openness and shared values which is unprecedented in the histories of either nation."

Yet, only last month, the CBS Evening News was reporting instances on the West Coast of Japanese firms laying off Americans first, and Japanese second in a marketing downturn. Is it the beginning of a pattern? Or is it merely an episode? It is events such as that, or the manner in which they are reported, that will continue to sow distrust between the two countries.

So after more than two decades of perceiving a "threat" from Japan's technological advances, the U.S. seems to be coming to the point of viewing Japan with clearer eyes. But, as MIT's Samuels points out, contact is still difficult. American pride is hurt by Japanese success. Japan in its way does not really like the feeling of being number one in anything and thus is uncomfortable with any leadership role.

Cutler says he observed during his year in Japan, though, a new young breed of Japanese technical professionals, ones who have managed to acquire Western habits of direct personal communication without the protection of lengthy ceremony. And, says Brian Moore, a researcher at the Japan External Trade Organization in New York, they seem to enjoy it. "When they get used to interacting with Americans," he says, "they begin to open up. They find it to be easier to be more straightforward. They find they enjoy the freedom in being able to speak up right away."

Adds Frost, "There's no question that the Japanese need foreign pressure because they've had long-entrenched elites and an insular mentality left over from the past. They have that group-oriented system that keeps out not only foreigners but other Japanese. It's hard for new businesses to break into their clubby structure. So they need pressure from the outside to break down those barriers.

"They're the first nonwhite country to get into the white man's club. But they need us, for our markets, for our universities, for our sciences, for our agriculture and raw materials. Their elites think we are the pillar of free trade and investment. They feel there is no meaningful alternative to the U.S.

"And though they are a monoculture with a deep pride in their race, they are an extremely pluralistic society. They have a legal and flourishing communist party. The gap between the old and the young is as wide as anywhere in the world. There is a whole generation with no memory of World War II. It's a tremendously cacaphonic society with all kinds of openness. Its press is relentless in exposing corruption."

But with all the cacaphony is that singular vision in Japan of getting better at what it chooses to excel in. It may feel as though it is still a nation of rice farmers needing their subsidies to survive, but its real power is in technology.

As Dineen says in his Japan-America Society paper, "The Japanese offer the long-term perspective necessary to push basic research to its fruition. American individualism, however, is most likely to provide the 'spark of genius' that makes basic research successful. Both countries, therefore, should work together to gain the rewards that appropriate cooperative endeavors in basic science and technology can bring."

A concluding point RPI's Peters makes in her report cautions U.S. policy makers against overreacting to a technologically potent Japan. "The ties with Japan can be used to invigorate and complement our vast resources," she says. "One can liken the situation to a muscle cramp. The worst antidote is to tighten up." □

Top 50 Chemicals Production Turned Back Up in 1987

Output increased 5.5% after slipping slightly in 1986 as organic chemicals moved up 5.5% and inorganic chemicals rebounded to rise 4.9%

Marc S. Reisch, C&EN New York

A surge in exports of chemicals last year helped boost U.S. chemical output dramatically. According to C&EN's annual ranking of the 50 largest-volume chemical products, total production in that group in 1987 increased 5.5% from 1986 to 567 billion lb. This marked a dramatic improvement over 1986 when total production of the Top 50 chemicals dropped 0.9% from the previous year.

The recovery was all the more dramatic considering that last year imports continued to grow, but at a much slower rate than they did in previous years. A decline in the value of the dollar helped make U.S. chemicals more attractive to overseas purchasers, and thus U.S. export volume increased markedly.

Demand in the U.S. markets for chemicals did little to produce the dramatic improvement in overall chemical production. The housing market was virtually flat. The auto market was down moderately. However, the U.S. farm economy began to stir and showed some small signs of improvement.

Among the largest-volume chemicals produced in the U.S., sulfuric acid continued to reign as king, with production last year totaling 77.5 billion lb, a 5.2% increase from 1986. Nitrogen continued to rank a distant second, with production at 47.3 billion lb, down 2.7% from 1986.

Organic chemicals, comprising 36% of the Top 50, made a good showing, but that segment of the Top 50 did not do so well as it did in 1986. Production of those substances increased 5.5% from 1986, compared with a 9.3% year-to-year increase in 1986. Between 1982 and

About the Top 50 list of chemical products

Government data, trade association figures, and industry estimates all go into preparing C&EN's annual list of the Top 50 chemical products, ranked by production volume. The federal government is relied upon most heavily, but when government figures are not available, other sources, primarily trade associations, are used. Industry sources and C&EN estimates are used only when other data are lacking.

Government data are not always accurate—they are only as good as the information that individual companies report. But they are an objective measure of production extending back many years. Therefore, relatively accurate indications of growth can be made on a consistent basis.

At this time of year, C&EN has access only to preliminary reports of production for 1987. When the government and trade associations issue their final reports, the outcome can be changed, sometimes dramatically. As a result, the production figures for earlier years that appear in the table on page 31 are different in some cases from those published in last year's Top 50 report. The final reports also can affect the rankings of chemicals. The 1986 rankings of 16 chemicals listed in the table, for example, are different from those in the similar table published by C&EN a year ago (C&EN, April 13, 1987, page 20).

The list itself covers production figures for the U.S. and includes chemicals produced for export. Candidates for the list include all basic, intermediate, and chemically homogeneous finished products. These range from chemical building blocks like ethylene and propylene to downstream products like vinyl acetate and ethylene glycol.

The roster also includes basic inorganic chemicals, but does not include what C&EN considers to be minerals, such as salt, gypsum, and sulfur. Lime is included because it is processed and has many chemical and industrial applications. Refractory (dead-burned) dolomite is excluded in the calculations of lime production.

In the organics list, such petrochemical feedstocks as ethane, butane, and propane are excluded arbitrarily because they are considered to be products of oil companies and because they have many nonchemical uses.

There are other gray areas besides lime and petrochemical feedstocks. For example, the basic aromatics—benzene, toluene, and xylene—are included. Admittedly, this makes the list less pure chemically.

Production figures are published by the government and trade associations in a variety of units—millions of pounds, thousands of tons, billions of cubic feet, millions of gallons, metric tons. To provide an accurate ranking and to make comparison of production volumes easier, C&EN not only gives production in common units but converts production to billions of pounds as well.

Top 50 chemicals production totaled 567 billion lb in 1987

Rank			Billions of lb		Common units[b]		Average annual growth			
1987	1986[a]		1987	1986	1987	1986	1986-87	1985-86	1982-87	1977-87
1	1	**Sulfuric acid**	77.49	73.64	38,748 tt	36,822 tt	5.2%	−7.1%	3.1%	1.1%
2	2	**Nitrogen**	47.32	48.62	653 bcf	671 bcf	−2.7	2.4	6.2	8.5
3	4	**Ethylene**	34.99	32.81	34,992 mp	32,811 mp	6.6	9.9	7.4	4.5
4	6	**Ammonia**	32.32	28.01	16,161 tt	14,005 tt	15.4	−19.1	0.5	−0.3
5	3	**Oxygen**	32.28	33.03	390 bcf	399 bcf	−2.3	1.5	2.2	0.2
6	5	**Lime[c]**	30.36	29.67	15,182 tt	14,834 tt	2.3	−6.1	1.5	−2.2
7	7	**Sodium hydroxide**	23.03	21.38	11,517 tt	10,691 tt	7.7	−1.9	4.2	0.9
8	8	**Chlorine**	21.93	20.87	10,963 tt	10,436 tt	5.0	0.4	3.6	0.5
9	9	**Phosphoric acid**	20.95	18.41	10,473 tt	9,206 tt	13.8	−12.5	4.9	2.8
10	10	**Propylene**	18.53	17.34	18,527 mp	17,343 mp	6.8	16.5	8.1	6.3
11	11	**Sodium carbonate[d]**	17.78	16.88	8,891 tt	8,438 tt	5.4	−1.8	2.6	5.5
12	14	**Urea[e]**	14.86	12.06	7,431 tt	6,029 tt	23.3	−9.7	2.8	6.6
13	13	**Nitric acid**	14.20	13.12	7,102 tt	6,562 tt	8.2	−10.9	−0.8	−0.9
14	12	**Ethylene dichloride**	13.81	14.53	13,805 mp	14,529 mp	−5.0	20.1	12.6	5.6
15	15	**Ammonium nitrate[f]**	12.83	11.11	6,416 tt	5,556 tt	15.5	−18.0	−2.0	−1.1
16	16	**Benzene**	11.67	10.23	1,585 mg	1,389 mg	14.1	8.9	8.5	1.1
17	17	**Carbon dioxide[g]**	9.84	9.77	4,922 tt	4,883 tt	0.8	−2.3	5.2	9.6
18	18	**Ethylbenzene**	9.41	8.92	9,409 mp	8,915 mp	5.5	20.7	7.2	5.0
19	19	**Vinyl chloride**	8.23	8.42	8,230 mp	8,415 mp	−2.2	−11.1	10.9	3.8
20	21	**Terephthalic acid[h]**	8.11	7.68	8,110 mp	7,684 mp	5.5	18.4	10.9	1.2
21	20	**Styrene**	8.09	7.84	8,090 mp	7,838 mp	3.2	2.8	6.4	2.5
22	22	**Methanol**	7.29	7.33	7,292 mp	7,327 mp	−0.5	46.5	−0.7	1.6
23	25	**Toluene[i]**	6.73	5.82	928 mg	802 mg	15.7	14.7	5.4	−0.7
24	24	**Formaldehyde[j]**	6.08	5.89	6,077 mp	5,885 mp	3.3	5.0	4.8	1.1
25	26	**Xylene**	5.72	5.55	795 mg	771 mg	3.1	4.5	3.9	1.0
26	23	**Ethylene oxide**	5.62	5.94	5,623 mp	5,943 mp	−5.4	9.4	2.4	3.0
27	27	***p*-Xylene**	5.15	5.00	5,152 mp	4,995 mp	3.1	4.5	9.9	5.9
28	28	**Hydrochloric acid**	4.99	4.83	2,495 tt	2,413 tt	3.4	−14.0	0.4	−0.2
29	29	**Ethylene glycol**	4.52	4.76	4,515 mp	4,759 mp	−5.1	13.9	0.9	3.1
30	30	**Ammonium sulfate**	4.37	4.17	2,183 tt	2,086 tt	4.7	−0.3	4.3	0.8
31	31	**Cumene**	4.15	3.70	4,151 mp	3,695 mp	12.3	10.5	8.6	4.3
32	41	**Methyl *tert*-butyl ether[k]**	3.37	2.24	3,372 mp	2,237 mp	50.7	18.3	32.6	nm
33	33	**Phenol[l]**	3.24	2.92	3,241 mp	2,921 mp	11.0	5.2	9.9	4.3
34	32	**Acetic acid**	3.23	2.93	3,227 mp	2,931 mp	10.1	1.2	3.3	2.7
35	35	**Butadiene[m]**	3.00	2.59	3,002 mp	2,593 mp	15.8	10.8	9.4	−1.5
35	34	**Potash[n]**	3.00	2.65	1,360 tmt	1,202 tmt	13.1	−7.3	−5.3	−4.6
37	35	**Carbon black**	2.72	2.59	2,724 mp	2,585 mp	5.4	0.5	3.4	−1.0
38	37	**Propylene oxide**	2.61	2.48	2,608 mp	2,480 mp	5.2	3.3	9.2	3.6
39	39	**Acrylonitrile**	2.55	2.31	2,551 mp	2,314 mp	10.2	−1.4	4.6	5.3
40	40	**Vinyl acetate**	2.51	2.25	2,505 mp	2,249 mp	11.4	6.5	6.0	5.4
41	38	**Aluminum sulfate**	2.45	2.44	1,223 tt	1,222 tt	0.1	−3.6	1.2	0.2
42	42	**Cyclohexane**	2.25	2.07	2,250 mp	2,071 mp	8.6	25.0	12.0	0.3
43	43	**Acetone**	2.08	1.94	2,082 mp	1,936 mp	7.5	8.3	4.2	1.1
44	44	**Titanium dioxide**	1.90	1.86	952 tt	931 tt	2.3	8.3	7.7	2.9
44	45	**Sodium silicate**	1.90	1.57	948 tt	786 tt	20.6	9.0	7.4	2.4
46	47	**Sodium sulfate[o]**	1.61	1.55	805 tt	775 tt	3.9	−6.3	−1.4	−4.2
47	48	**Adipic acid**	1.57	1.52	1,572 mp	1,522 mp	3.3	4.7	6.3	0.4
48	46	**Calcium chloride[p]**	1.55	1.56	773 tt	780 tt	−0.9	−2.6	−2.0	−4.3
49	49	**Isopropyl alcohol**	1.31	1.28	1,313 mp	1,275 mp	3.0	3.2	−1.0	−3.8
50	50	**Caprolactam**	1.16	0.85	1,161 mp	850 mp	36.6	−21.5	7.9	4.1
TOTAL ORGANICS			201.85	189.17			5.5%	9.3%	7.1%	2.7%
TOTAL INORGANICS			364.83	347.74			4.9%	−5.7%	2.3%	−0.1%
GRAND TOTAL			566.68	536.91			5.5%	−0.9%	4.8%	1.3%

a Revised. **b** **tt** = thousands of tons, **bcf** = billions of cubic feet, **mp** = millions of pounds, **mg** = millions of gallons, **tmt** = thousands of metric tons. **c** Except refractory dolomite. **d** Natural and synthetic. **e** 100% basis. **f** Original solution. **g** Liquid and solid only. **h** Includes both acid and ester without double counting. **i** All grades. **j** 37% by weight. **k** Production data for earlier years unavailable. **l** Synthetic only. **m** Rubber grade. **n** K_2O basis. **o** High and low purity. **p** Solid and liquid. **nm** = not meaningful.

1987, production of organic chemicals among the Top 50 increased 7.1% a year. Over the long term, however, their output has grown at a much slower pace. Between 1977 and 1987, output of organic chemicals among the Top 50 has grown only at a rate of 2.7% a year.

However, the inorganic segment of the Top 50 made a dramatic recovery in 1987. Production increased 4.9%, following a 5.7% decline in 1986. Within that segment, output of the major fertilizer chemicals was up—including phosphoric acid, up 14%; urea, up 23%; and potash, up 13%. Other big-volume inorganics also showed improvements. Nitric acid production increased 8.2%, and ammonium nitrate production increased 16%.

Of the Top 50 chemicals, production of 42 of them increased in 1987. By contrast, production of only 19 increased in 1986. Although total production of the Top 50 chemicals, at 567 billion lb, was up 5.5% from 1986, it was down 1.4% from the Top 50 historical high of 575 billion lb in 1979. The 1987 production level was 22% higher than the decade-low production level of 464 billion lb registered in 1982.

For the Top 50 group, composite output increased at a compound annual rate of 4.8% between 1982 and 1987. However, indicative of long-term growth, Top 50 production grew at an average annual rate of 1.3% between 1977 and 1987.

As a group, organic chemicals outperformed the inorganics, however. Showing the largest production increase on the organics side was methyl *tert*-butyl ether. Production of that chemical was up 51% to 3.37 billion lb. The gain pushed that chemical to 32nd place in 1987 from 41st place in 1986.

Next in terms of percentage gains among the organics was caprolactam, up 37% to 1.16 billion lb. The increase gained the chemical's entry into the Top 50 at 50th place in 1987. It did not appear on the list for 1986 (C&EN, April 13, 1987, page 20).

Also up appreciably in terms of percentage gains were urea, with output up 23% to 14.9 billion lb following a 9.7% decline in 1986; butadiene, up 16% to 3.0 billion lb; toluene, up 16% to 6.73 billion lb; and benzene, up 14% to 11.7 billion lb.

Not all the organics gained, however. The biggest decreases came from ethylene oxide, whose production was down 5.4% from the previous year, and ethylene glycol, down 5.1%.

For inorganic chemicals, 1987 production was led by sodium silicate, up nearly 21% from 1986 to 1.90 billion lb. Sodium silicate also led the pack in production growth in 1986, when production grew 9.0%. Also showing very good production increases in 1987 were ammonium nitrate, up 16% to 12.8 billion lb following an 18% decline the previous year; and ammonia, up 15% to 32.3 billion lb following a 19% decline in 1986.

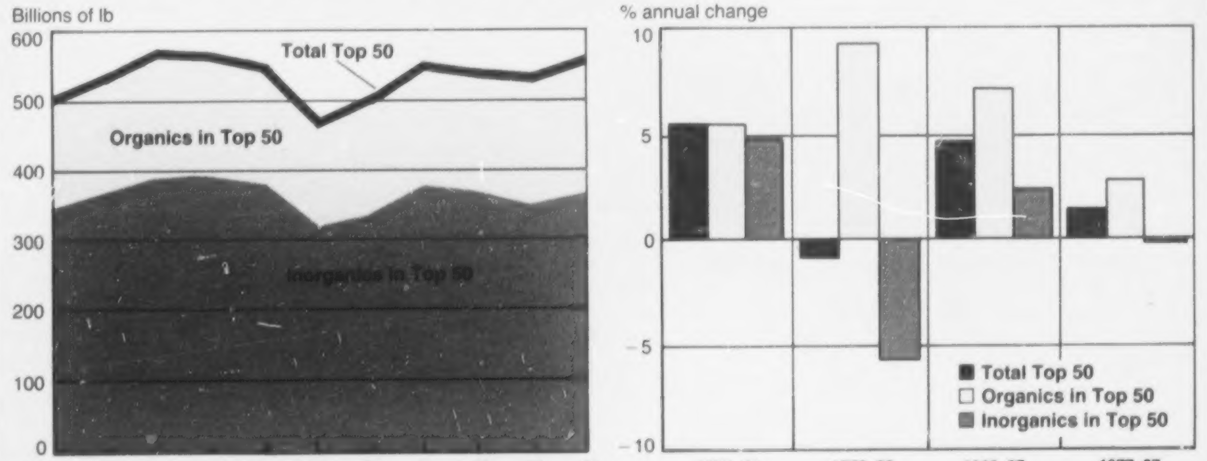
Other large-volume inorganic chemicals that had large swings in production last year were phosphoric acid, up 14% to nearly 21 billion lb, following a 13% decline a year earlier; and potash, up 13% to 3.0 billion lb in 1987 following a 7.3% decline in 1986.

Over the past five years, 43 of the Top 50 chemicals have registered increases in production. Leading in individual increases over the five-year span was methyl *tert*-butyl ether, whose production grew at an annual compound rate of almost 33%. Next were ethylene dichloride, up about 13% annually for the five-year period; cyclohexane, up 12% a year; vinyl chloride, up 11% a year; and terephthalic acid, also up 11% a year.

On the downside of production, leading the products with the largest individual decreases over the five-year period was potash, whose output fell at a compound annual rate of 5.3%. Other chemicals registering decreases over the five-year period were ammonium nitrate, down 2.0% a year; calcium chloride, also down 2.0% a year; sodium sulfate, down 1.4% a year; and isopropyl alcohol, down 1% a year.

Looking at growth over the past 10 years, 39 of the Top 50 chemicals have recorded overall production

Production of Top 50 chemicals is on the upswing



increases. The best long-term performer has been carbon dioxide, whose output grew at an annual compound rate of 9.6% during this period. Production of nitrogen also grew at a remarkable rate of 8.5%. Other chemicals with sizable growth rates were urea, up 6.6% a year, and propylene, up 6.3% per year.

Potash registered the greatest average annual rate of decline over the past 10 years. Its output has fallen at a compound annual rate of 4.6%. Other products with shrinking output were calcium chloride, down 4.3% a year; sodium sulfate, down 4.2% a year; isopropyl alcohol, down 3.8% a year; and lime, down 2.2% a year.

The group comprising the 10 largest chemical commodities in terms of production was the same in 1987 as it was in 1986. Some commodities within that group, however, switched places in ranking. Ethylene, for example, which ranked third in volume in 1987, was fourth in terms of production in 1986. Ammonia moved up to fourth place from sixth place a year earlier. Oxygen moved down to fifth place from third place in 1986, and lime slipped a notch to sixth place after ranking fifth place a year earlier.

There was a good deal of rank shifting thoughout the rest of the list. In all, 21 of the chemicals either moved up or down in the rankings.

Besides the rise for ethylene and ammonia and the fall of oxygen and lime already noted, there were other significant changes. Some upward movements included methyl *tert*-butyl ether, with its 51% increase in production in 1987, which jumped to 32nd place from 41st in 1986. Other large changes included urea, which jumped to 12th place from 14th, and toluene, which moved up to 23rd place from 25th. □

Polymer output records fifth consecutive annual rise

Overall production of plastics, synthetic fibers, and synthetic rubber polymers reached a record high of 57 billion lb in 1987. The growth marked the fifth consecutive annual increase for the product group, lifting the output total 9.1% above the 1986 record.

Plastics, which account for more than two thirds of the polymer group production totals, continued their buoyant growth in 1987. Production was up 9.9% from 1986. The strongest growth among plastics was registered by the thermoplastic resins, up 10%. Of such resins, polypropylene continued to show the highest growth, up 14%; followed by high-density polyethylene, up 12%; polyvinyl chloride and copolymers, up 9.9%; low-density polyethylene, up 8.3%; and polystyrene, up 7.7%.

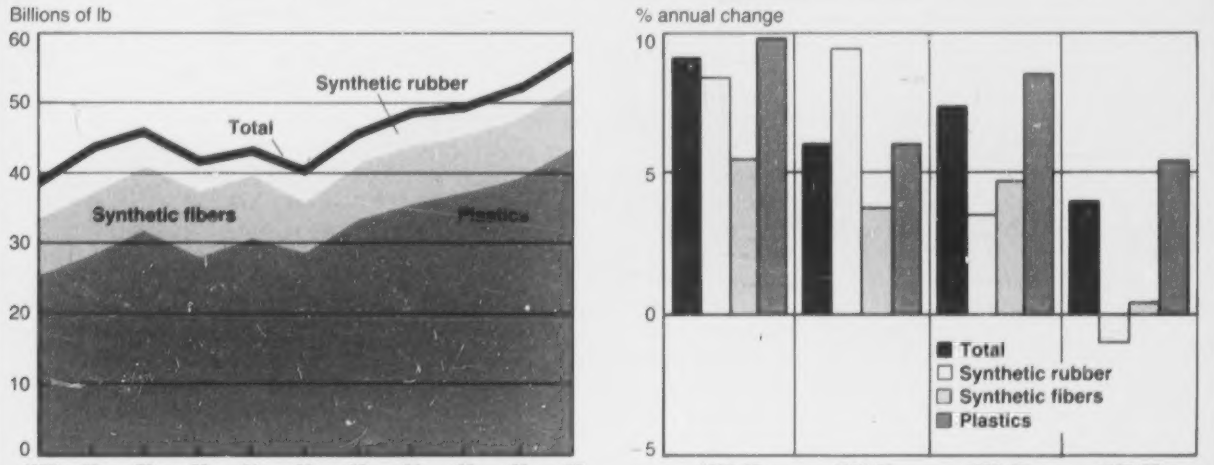
By comparison, output of thermosetting resins grew 7.4% in 1987. Melamine resins made a spectacular recovery in 1987, up 23%, following a dismal performance a year earlier when production dropped 9.9%. Production last year at 212 million lb marked a decade high for melamine resins production. The previous high was in 1984, when industry produced 210 million lb of the resins.

Showing good though less remarkable gains were epoxy resins, up 8.8% in 1987; urea resins, up 8.7%; polyesters, up 7.8%; and phenol and other tar acid resins, up 5.4%.

For the five-year period between 1982 and 1987, the plastics segment grew at an annual compound rate of 8.5%. For the 10-year period between 1977 and 1987, plastics grew at an annual compound rate of 5.4%.

Synthetic rubber output increased 8.4% in 1987. Production of 4.8 billion lb last year matched the 4.8 billion high of 1984, but the category's output is still running 17% below the decade high of 5.6 billion lb in 1979.

Output of plastics, synthetic fibers, and synthetic rubbers continued to climb in 1987



Total polymer production exceeded 57 billion lb last year

	Billions of lb		Common units					Average annual growth			
	1987	1986	1987	1986	1985	1982	1977	1986–87	1985–86	1982–87	1977–87
PLASTICS (millions of lb)											
Thermosetting resins	**6.26**	**5.83**	**6,266**	**5,834**	**5,631**	**4,367**	**3,943**	**7.4%**	**3.6%**	**7.5%**	**4.7%**
Phenol, other tar acid resins	2.87	2.72	2,869	2,721	2,621	2,060	1,458	5.4	3.8	6.8	7.0
Urea resins	1.38	1.27	1,382	1,271	1,210	998	963	8.7	5.0	6.7	3.7
Polyesters (unsaturated)	1.37	1.27	1,370	1,271	1,223	865	1,061	7.8	3.9	9.6	2.6
Epoxies (unmodified)	0.43	0.40	433	398	385	286	261	8.8	3.4	8.6	5.2
Melamine resins	0.21	0.17	212	173	192	158	200	22.5	−9.9	6.1	0.6
Thermoplastic resins	**37.03**	**33.57**	**37,028**	**33,569**	**31,525**	**24,425**	**21,569**	**10.3%**	**6.5%**	**8.7%**	**5.6%**
Low-density polyethylene	9.63	8.89	9,629	8,888	8,889	7,503	6,471	8.3	−1.1	5.1	4.1
PVC and copolymers	7.97	7.26	7,971	7,256	6,772	5,326	5,253	9.9	7.1	8.4	4.3
High-density polyethylene	8.00	7.17	7,999	7,171	6,671	4,928	3,652	11.5	7.5	10.2	8.2
Polystyrene[a]	4.78	4.44	4,782	4,442	4,054	3,191	3,446	7.7	9.6	8.4	3.3
Polypropylene	6.65	5.81	6,647	5,812	5,139	3,477	2,747	14.4	13.1	13.8	9.2
TOTAL[b]	**43.29**	**39.40**	**43,294**	**39,403**	**37,156**	**28,792**	**25,512**	**9.9%**	**6.0%**	**8.5%**	**5.4%**
SYNTHETIC FIBERS (millions of lb)											
Cellulosics	**0.61**	**0.62**	**605**	**619**	**556**	**584**	**888**	**−2.3%**	**10.9%**	**0.7%**	**−3.8%**
Rayon	0.41	0.40	414	404	353	388	598	2.5	14.4	1.3	3.6
Acetate[c]	0.19	0.22	191	215	205	196	290	−11.2	4.9	−0.5	−4.1
Noncellulosics[b]	**8.30**	**7.82**	**8,298**	**7,815**	**7,564**	**6,442**	**6,911**	**6.2%**	**3.3%**	**5.2%**	**1.8%**
Polyester[d]	3.54	3.31	3,541	3,305	3,341	3,168	3,642	7.1	−1.1	2.3	−0.3
Nylon	2.69	2.51	2,688	2,514	2,343	1,927	2,326	6.9	7.3	6.9	1.5
Olefins[e]	1.48	1.38	1,478	1,380	1,249	723	234	7.1	10.5	15.4	20.2
Acrylic[f]	0.59	0.62	591	616	631	624	709	−4.1	−2.4	−1.1	−1.8
TOTAL[b]	**8.90**	**8.43**	**8,903**	**8,434**	**8,122**	**7,026**	**7,799**	**5.6%**	**3.8%**	**4.8%**	**0.4%**
SYNTHETIC RUBBER (thousands of metric tons)											
Styrene-butadiene[g]	1.87	1.75	850	792	735	876	1,395	7.3	7.8	−0.6	−4.8
Polybutadiene	0.82	0.74	371	336	330	288	361	10.4	1.8	5.2	0.3
Ethylene-propylene	0.56	0.51	254	230	215	123	158	10.4	7.0	15.6	4.9
Nitrile	0.15	0.13	69	59	53	45	70	16.9	11.3	8.9	−0.1
Other[h]	1.41	1.31	638	596	505	497	433	7.0	18.0	5.1	4.0
TOTAL[b]	**4.81**	**4.44**	**2,182**	**2,013**	**1,838**	**1,829**	**2,417**	**8.4%**	**9.5%**	**3.6%**	**−1.0%**

a No longer includes acrylonitrile-butadiene-styrene or styrene-acrylonitrile resins; historical data are restated. **b** Totals are for those products listed. Totals may not add because of rounding. **c** Includes diacetate and triacetate yarn, but does not include cigarette tow. Beginning with 1985, includes rayon yarn. **d** Excludes aramid after 1982. **e** Includes olefin film, olefin fiber, spud-bonded polypropylene, and vinyon. **f** Includes modacrylic. **g** Excludes high-styrene latex. **h** Beginning with 1985, includes neoprene; historical data are restated. Also includes butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. **Sources:** Society of the Plastics Industry, Textile Economics Bureau, Rubber Manufacturers Association

All segments of the synthetic rubber category registered increases in production in 1987. Nitrile rubber showed the largest rise at 17%, following a 11% increase in 1986. Both polybutadiene and ethylene-propylene rubber production grew 10% in 1987. The increase in polybutadiene production was the most remarkable, following a 1.8% increase in 1986. Ethylene-propylene rubber's 1987 growth follows a 1986 growth of 7.0%.

Production growth of styrene-butadiene rubber slowed in 1987 to 7.3% from a 7.8% growth rate in 1986. Also putting in a showing that was not quite as good as the year earlier were the synthetic rubber products reported as a group by the Rubber Manufacturers Association: neoprene; butyl; polyisoprene; chlorosulfonated polyethylene; polyisobutylene; and acrylo, fluoro, and silicone elastomers. Production of that group grew 7.0% in 1987, compared with 18% in 1986.

Over the past five years, the synthetic rubber category has not grown so rapidly as it has in the past two years. Synthetic rubber production has grown at an average annual rate of 3.6% over the past five years. For the past 10 years, production has actually declined at an average annual rate of 1.0%.

Though still the slowest-growing of the entire polymers product group, synthetic fibers nevertheless recorded a respectable production increase of 5.6% in 1987 over the year-earlier level. Despite continued pressure from imported textiles, noncellulosics showed the most impressive gains. However, cellulosics declined in part because of discontinuation of U.S. triacetate production.

Output of noncellulosics recorded the best gain, rising 6.2% in 1987. The group accounted for more than 90% of total fiber production last year. Olefins continued to lead in growth; they were up 7.1% in 1987. Matching that rate of increase was polyester; staple and filament production both grew in 1987. The recovery for polyester followed a 1.1% decline in 1986. Nylon was up 6.9% in 1987 as demand for new generation broadloom continued. The only poor showing was from acrylic fiber, production of which continued to flounder. Output dropped 4.1% in 1987 following a 2.4% decline in 1986. □

A1250-1
4/18/88

APRIL 18, 1988
CHEMICAL & ENGINEERING
NEWS

0511179C098 9 K AR6616SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

George C. Pimentel wins 1989 Priestley Medal

Page 17

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 16
CENEAR 66 (16) 1-40
ISSN 0009-2347

APRIL 18, 1988

News of the Week

■ **Soviet health officials visit U.S. in attempt to finally put to rest continuing questions about a 1979 anthrax outbreak, maintaining that it was caused by tainted meat and not an accidental release from a suspected biological warfare facility.** **Page 4**

■ **U.S. producers of styrofoam plates, bowls, and fast-food containers will stop using fully halogenated chlorofluorocarbons by year's end.** **Page 5**

■ **Two-pronged program—a mobil exhibition and teams of speakers—aimed at enhancing the image of chemistry to the public has been launched by the U.K.'s Chemical Industries Association.** **Page 5**

■ **Possible use of criminal sanctions against scientific fraud, suggested at recent Congressional hearings on cheating in research, drew strong protests from researchers.** **Page 6**

■ **Joint venture to make PVC and formation of a consortium of U.S. firms to promote trade between the U.S. and the Soviets are the outgrowth of recent Moscow trade talks.** **Page 6**

Cover: Photo by C&EN's Rudy M. Baum

Letters **2**

Concentrates

Business **7**
Government **12**
Science/Technology **16**

The Departments

People **26**
Awards **28**
Newscripts **40**

Business

Vista Chemical is striving to expand its business in Europe, sees markets there contributing significantly to its sales this year. **Page 9**

Government

Chemists applying for funds from NSF are more likely to seek them from NSF divisions other than the chemistry division, a survey shows. **Page 14**

Technology

A microelectronic chemical sensor that can detect several kinds of hazardous gases has been developed by researchers at Sandia National Laboratories. **Page 21**

Method that uses urea to remove nitrogen oxides from flue gas shows promise as cost-effective route to reduce atmospheric pollution. **Page 22**

Books

"Knowing Everything About Nothing" by John Ziman offers practical advice to scientists who are considering career changes. **Page 23**

ACS News

Energy research funding, basic research support at NSF, and federal employment practices are issues of concern to chemists addressed by ACS recently in letters to several Congressional committees. **Page 25**

Priestley Medal

A quintessential basic researcher and a leader in chemical education and in the chemistry profession, George C. Pimentel, professor of chemistry at the University of California, Berkeley, is the 1989 recipient of ACS's Priestley Medal. **Page 17**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 39)

LETTERS

CHEMICAL SAFETY

Nitroacyl halide instability

SIR: A recent report of a vigorous decomposition at 60 °C when 3-methoxy-2-nitrobenzoyl chloride was heated with copper (I) cyanide to form the acyl nitrile attributed this to thermal instability of the latter [Goodwin, B., *Chem. Brit.*, **23**, 1180 (1987)].

Available evidence suggests that the real cause was much more probably the well-documented low thermal stability of several nitroaryl acyl halides (both carbonyl and sulfonyl), particularly when the nitro group is adjacent to the acyl halide function, and the decomposition temperature would be expected to be lowered by presence of the copper salt.

In this case, however, there is the additional possibility of demethylation of the 3-methoxy group by traces of hydrogen chloride in the starting material, self-condensation of the resulting hydroxy-nitrobenzoyl chloride (with liberation of hydrogen chloride to keep the exothermic demethylation-condensation sequence going), eventually leading to violent decomposition of the poly (nitroester). This sequence was established in detail for the isomeric 4-methoxy-3-nitrobenzoyl chloride, which in temporary storage at 100 °C led to violent decomposition at over 350 °C and a double explosion involving the chloromethane liberated by demethylation [Grewer, T., *Chem. Ing. Tech.*, **49**, 962 (1977)]. Again, copper salts would catalyze some of the reactions involved in the recent incident.

L. Bretherick
Bridport, Dorset, U.K.

Herbicide development clarified

SIR: I wish to clarify the statement (C&EN, March 7, page 24) about my involvement with Monsanto's herbicide Roundup. My group did not develop the product, although I certainly wish we had. Rather, our group developed key catalytic technology used in its manufacture.

James F. Roth
Allentown, Pa.

Plastic handguns

SIR: In the letter on plastic handguns (C&EN, March 7, page 4) Alan Nixon makes two points. One clearly proves that the other is not valid. Specifically, he pleads the case for C&EN to speak out in areas not confined to the fields normally a formal part of ACS or C&EN. He cites as an example the so-called plastic gun. Clearly this shows why we must be careful to stay in our areas of professional expertise. Even a superficial investigation of the facts will show there is no such thing as a plastic gun, nor is current materials science likely to make one possible in the foreseeable future.

The required strength of a plastic to withstand the fast burning of the propellent of a modern cartridge is far beyond any existing plastic. What the antigun forces call a "plastic gun" is simply a rather standard handgun with grips and body of a high-grade polymer. The barrel, springs, firing pin, and indeed most of the weapon is of standard steel components. Further numerous tests with standard airport security x-ray equipment prove even disassembled it clearly is seen as a weapon by properly trained and attentive security personnel. The problem of airport security is not mythical plastic guns, but poor training and lax enforcement—as recent Federal Aviation Administration trials have shown.

Given the obvious lack of factual basis for Nixon's concern about plastic guns, I submit this is a perfect example of why we should stay within our professional area as far as C&EN is concerned. Certainly as a citizen any member can and should become involved in political questions of interest. I hope this fine technical publication will not become diluted as a political forum.

Jack Jacox
Columbus, Ohio

Hazards of environmentalism

SIR: The comments by Richard K. Long (C&EN, March 14, page 3) on the image of chemicals may represent an appropriate and advantageous short-term strategy for Dow's director of corporate communications speaking to the Public Relations Society of America.

But he may also be confusing temporary illusion and deception with reality, and he may misunderstand or misinterpret virtually everything about the nature of modern environmentalism, including inherent hazards.

One of the illusions that Long accepts is, "Much of the public considers clean

NSF Probes Applicants' Perception Of Proposal Review System

Survey shows chemists are less likely to seek funding only from their own NSF division; most rejectees felt proposal turndowns were fair

In fiscal 1985, 9% of the 14,000 proposals acted on by the National Science Foundation came from academic individual investigators who defined their primary field of research as chemistry. These chemists were less likely than other scientists, except physicists, to seek support only from their own (chemistry) division; just under 60% of their proposals went to the chemistry division.

Yet 90% of the 799 proposals acted on by the chemistry division came from chemists. Physicists, biochemists, and chemical engineers accounted for another 6% of the proposals. More than 29% of the applicants to the chemistry division define themselves as consistent rejectees having had two or more of the proposals they submitted to NSF over five years turned down. However, the majority felt that the decision to decline their proposal was "fair." Chemistry division applicants also are much more likely than other applicants to submit a declined proposal to another agency for funding; 22% of them preferred the National Institutes of Health as a source of funding.

These are just a few of the facts to be gleaned from a new report, "Proposal Review at NSF: Perceptions of Principal Investigators." The report presents the results of a survey conducted by NSF in late 1986 of more than 14,000 applicants from academic institutions whose proposals for research support had been awarded or declined during fiscal year 1985. About 88% of survey recipients who received grants in fiscal 1985 responded, as did 52% of those whose proposals had been declined. Altogether, more than two thirds of those surveyed responded.

For the foundation as a whole, 34% of the proposals from the surveyed population were awarded. The rates varied from a high of just under 60% for atmospheric sciences to a low of about 15% for research initiation and improvement. The

Chemists more apt to seek funds from other NSF divisions

Number of proposals	Biochemistry	Chemical engineering	Chemistry	Mathematics	Materials research	Physics
Biological, behavioral, and social sciences	373	9	139	45	18	24
Behavioral, neural sciences	31		30	4	6	5
Biotic systems, resources	3		8	1		
Cellular biosciences		2	2	27	10	6
Molecular biosciences	339	6	99		2	10
Social, economic sciences		1		13		3
Computer and information science & engineering	0	2	0	21	0	17
Computer research		2		16		
Information science, technology				5		17
Engineering	7	349	65	24	14	47
Chemical, biochemical, thermal	3	304	34	2	2	
Design, manufacturing		1		1		
Electrical, communications, and systems	2		11	12		2
Emerging and critical systems		5	2	2	3	30
Mechanics, structures, and materials		9	6	7	9	8
Other	2	30	12			7
Geosciences	6	0	31	2	1	83
Atmospheric sciences			13	2		57
Polar programs			5			16
Earth sciences	3		9		1	5
Ocean sciences	3		4			5
Mathematical and physical sciences	17	20	844	974	147	529
Astronomical sciences						16
Chemistry	13	11	720	3	2	22
Materials research	2	8	115	3	143	248
Mathematics	2	1	1	966		8
Physics			8	2	2	235
Research initiation, improvement	13	18	27	23	8	8
Other[a]	68	29	153	60	16	63
TOTAL	**484**	**427**	**1259**	**1149**	**204**	**771**

[a] Program or division not reported or identified. **Source:** National Science Foundation

rate for chemistry was about 38%, materials research 35%, and chemical engineering 30%.

When asked their opinion of NSF's proposal review system, 80% of the awardees and 33% of those whose proposals were declined said they were satisfied with it. However, half of the rejectees, and some of the awardees, were dissatisfied with the process. A minority of the applicants described their feelings as "neutral." Those who didn't like the process came up with a number of reasons for their dissatisfaction. According to the report, young investigators were more likely to cite cursory reviews, and older investigators more likely to say that some reviewers had the wrong scientific background or were poorly chosen by the program officer. Dissatisfied applicants, primarily from undergraduate institutions, were more likely to cite bias toward big schools and politics and cronyism as sources of their dissatisfaction.

The survey also showed that investigators who wrote, telephoned, or visited a program officer before submitting a proposal were somewhat more likely to be funded than those who had not. The report notes that the survey did not address the reasons for this outcome, but experience shows that in many cases investigators decide not to submit a proposal after making contact with NSF. In other cases they are able to sharpen the proposal. The likelihood of an award also was much higher for applicants who said they knew the program officer prior to submitting an application.

Other results of the survey, according to the report, include:

- 75% of all applicants, and 97% of the consistently successful ones, had served as a reviewer or panelist for NSF at least once in the five years before the survey.
- For 29% of the applicants (51% of the women), the proposal that was the object of the survey was the first they had submitted to NSF as an independent private investigator.
- 20% of applicants were competing for further funding of current NSF-supported work, whereas 80%, some of whom had current NSF funding, said their proposal was for new work.
- 29% indicated that their proposal was for new work.
- 13% of the proposals were for less than $30,000, and 7% were for more than $150,000.
- The average elapsed time between proposal submittal and a decision was 7.4 months.
- 76% of the proposals were reviewed by mail and 42% by a panel; 16% didn't know how their proposals were reviewed.

Copies of the report can be obtained from the Forms and Publications Unit, Room 232, National Science Foundation, 1800 G St., N.W., Washington, D.C. 29550. Request NSF 88-4.

Janice Long, Washington

ANALYTICAL & ENVIRONMENTAL TRAINING COURSES

Upcoming Short Course Titles are:

COURSE TITLE	*COURSE NUMBER*
Mass Spectrometry & Spectral Interpretation, 3-Days	10
Environmental Laboratory QA/QC Data Validation, 2-Days	60
Toxicology for Managers, Engineers and Chemists, 1-Day	110

City and dates for these courses are:

Chicago, IL	**May 12–15**
Pittsburgh, PA	**June 6–11**
Orlando, FL	**June 27–31**
Albany, NY	**July 11–16**
St. Louis, MO	**August 15–20**
Riverside, CA	**January 23–28**

For course details contact Bob Nowicki at 412-262-4222 or write to PACS, Inc., 409 Meade Dr., Coraopolis, PA. 15108.

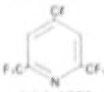
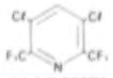
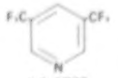
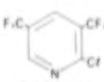
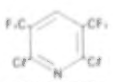
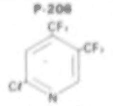
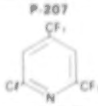
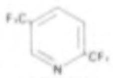
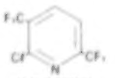
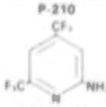
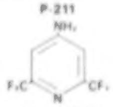
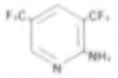
Professional Analytical & Consulting Services, Inc. provides GC/MS sample analysis, consulting and training courses. On-site training courses are available. Courses repeat every six months in Pittsburgh, PA. Customized educational materials may be developed for a clients needs.

Course titles and dates offered in Pittsburgh are available on request

CALL 412-262-4222

Organic Intermediates through Ishihara Sangyo's Advanced Technology:

NEW LUTIDINE DERIVATIVES

P-201  4,2,6-CBTF	P-202  3,5,2,6-DCBTF	P-203  3,5-BTFP
P-204  2,3,5-CBTF	P-205  2,6,3,5-DCBTF	P-206  2,4,5-CBTF
P-207  2,4,6-CBTF	P-208  2,5-BTFP	P-209  2,3,6-CBTF
P-210  2,4,6-ABTF	P-211  4,2,6-ABTF	P-212  2,3,5-ABTF

ISHIHARA SANGYO has added the above new compounds to its product line. Although these new developmental compounds are only in the research stage, small samples can be prepared for research and development purposes. We wish to make the best use of our processes to assist in the synthesis of your products.

ISK

ISHIHARA SANGYO KAISHA, LTD.
10-30, Fujimi 2-Chome, Chiyoda-ku, Tokyo, Japan, Telex 2324306 ISK J
ISK (EUROPE) S.A. 33/31 Rue Montoyer, Box 8 1040 Bruxelles
Tel (02)512-54-50·512-72-78 Telex 23362 ITDD B
ISHIHARA CORPORATION (U.S.A.) Transamerica Pyramid 42nd
Floor 600 Montgomery Street, San Francisco, Ca 94111
Tel 415-421-8207 Telex 278010 ICUSA UR

4/28/88
A1250-1

APRIL 25, 1988

CHEMICAL & ENGINEERING

NEWS

Foreign Investment

The increase in U.S. chemical industry continues
Page 7

0511179C098 9 K AR6617SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 17
CENEAR 66 (17) 1–48
ISSN 0009-2347

APRIL 25, 1988

News of the Week

- **Occidental Petroleum pays $2.2 billion for Cain Chemical, formed last year from the group of chemical commodities businesses that entrepreneur Gordon Cain and his investment banking group bought for about $800 million. Page 4**
- **Criminal charges for misconduct in research are brought against Stephen E. Breuning, a well-known researcher in drug therapy for mentally retarded children. Page 5**
- **Senate 1989 budget resolution sets ceilings for research and development spending and approves funding for construction of Super Conducting Supercollider. Page 5**
- **Two important steps were taken last week toward achieving nuclear test limits—the U.S. flew first load of monitoring equipment to Soviet's major test site and Soviet scientists in Nevada prepared equipment to monitor underground chemical explosions in that state. Page 6**

Cover: Hoechst Celanese chemical complex at Clear Lake, Tex.

Letters 2

Concentrates

Business 11
Government 17
Science/Technology 19

The Departments

ACS News 28
Meetings 30
People 47
Newscripts 48

Business

Profits have been rising steadily at France's Rhône-Poulenc, thanks to strong global chemical business and success of corporate restructuring. **Page 13**

Dedication ceremonies last week for a Hydro Fertilizers plant in Immingham, England, were attended by Princess Anne. **Page 16**

Government

Foreign funding of U.S. university R&D is too minimal to warrant concern about foreign expropriation of domestic technology. **Page 18**

Science

Carl Marvel's extraordinary influence on chemistry is chronicled in files donated to history center. **Page 20**

New electron-transfer chain reaction in which a carbanion donates a hydrogen atom and transfers an electron has been discovered. **Page 22**

First editor of ACS's newest journal, *Chemistry of Materials*, will be Rensselaer chemistry professor Leonard Interrante. **Page 23**

Technology

Gas Research Institute takes new look at its R&D programs, puts more emphasis on applications and gas's competition with electricity. **Page 24**

Field test of underground gasification of unminable western coal shows technique is technically feasible, can be commercialized. **Page 25**

Books

"Organic Chemistry: The Name Game. Modern Coined Terms and Their Origins" by Alex Nickon and Ernest F. Silversmith shares exuberance for the words of chemistry and has fun with their origins. **Page 26**

News Focus

Foreign companies continue to invest heavily in the U.S. chemical industry to complement their global businesses, lured by cheaper dollar and large U.S. market. Page 7

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 47)

LETTERS

Chemical weapons

SIR: One small sentence in a lengthy article on chemical weapons (C&EN, March 28, page 7): "The negotiators have yet to face this problem head-on." No one is clear as to whether 5000 or 10,000 persons have been killed recently in the Iran-Iraq war by use of chemical weapons. Can one say with any certainty that such weapons will not be used in a holier effort?

Negotiating is all very well, and I would hope that some progress were possible. Then I recall that the key players are supplying Iran and/or Iraq with chemical technology, long-range missiles, and a host of other devices to win the war. Did even one of the key players do more than condemn the recent Iraqi chemical attack? Yes, there is a very long way to go.

Harold B. Reisman
Weston, Conn.

Medical/medicine

SIR: Permit a retired physician to comment on Laurence J. White's letter (C&EN, Feb. 29, page 3) suggesting that we physicians could improve our public image if we were to belong to the American "Medicine" Association.

Our situation is exactly the opposite of yours, in that "medicine" as a common noun, used substantively or attributively, is the carrier of the poor image. Who wants medicine breath? Who could take seriously a medicine show? And I certainly would prefer to be called a medical man rather than a medicine man. Let White speak for his own profession.

F. Regis Riesenman
Arlington, Va.

Great Lakes cleanup

SIR: Your article, "The Great Lakes Cleanup Effort" (C&EN, Feb. 8, page 22) states that the use of fertilizers and phosphate detergents adds enormously to the amounts of phosphorus and nitrogen available to the lakes. This statement has never before been made in the published literature and is not correct.

Nationwide, the amount of phosphorus going into fertilizers is 29 times that which goes into detergents. The amount of phosphorus that runs off the farm in unused fertilizer and animal waste is 35 times that which runs into sewage treatment plants, before these plants, as do most around the Great Lakes, remove the phosphorus. The 1981 Great Lakes Surveillance Report to the International Joint Commission found that, of the total phosphorus entering the Great Lakes, only 14% came from municipal discharges, and that is after phosphorus removal. In terms of total phosphorus flowing into the lakes, detergents contribute less than 1%.

A human being's daily body wastes contain twice the phosphorus that a normal washing machine puts out per day and per person. If detergents made an enormous contribution, human waste, which is not mentioned, would be twice as large.

Quite independently of all these numbers, the inconsequential contribution of detergent phosphorus is verified by published studies on the effect of detergent phosphate bans [Wisconsin Department of Natural Resources 1982, ditto 1988, Purdue University 1986 (after 11 years of Indiana ban), Wendt 1982, Clesceri 1982, ditto 1985, Runke (Minnesota) 1980, etc.], all of which show that detergent bans have no effect on water quality.

C&EN on Jan: 6, 1986, quoted a joint committee of the U.S. National Research Council and the Royal Society of Canada to the effect that the major success story of the phosphorus control programs was increased investments in municipal sewage-treatment plants. Your recent article is inconsistent with this by claiming that same success now includes "decreasing the amounts of phosphate allowed in detergents" (page 26).

E. A. Matzner
Monsanto Chemical Co., St. Louis

Forum for information

SIR: Alan C. Nixon (C&EN, March 7, page 4) is ambivalent about using the letters column for soapboxing—unless it's something he is interested in. Very human and very understandable. I find the letters column one of the most informative spots. I would like to inform readers he was writing about bill S. 465. My understanding is that this bill is to ban guns with less than 8.5 oz of steel in an effort to make them detectable. Some people have called this a ban on plastic guns. I know of no plastic gun or any plans to manufacture such.

The bill also seeks to empower the Secretary of the Treasury to ban all guns he deems not "readily detectable." Many small legal guns do not contain 8.5 oz of steel. If these were arbitrarily

Foreign Investment in U.S. Chemical Industry Continues Steady Climb

Foreign companies own about one fourth of the U.S. chemical industry, attracted here by cheaper dollar, huge U.S. market, fewer government regulations, and political stability

Marc S. Reisch, C&EN New York

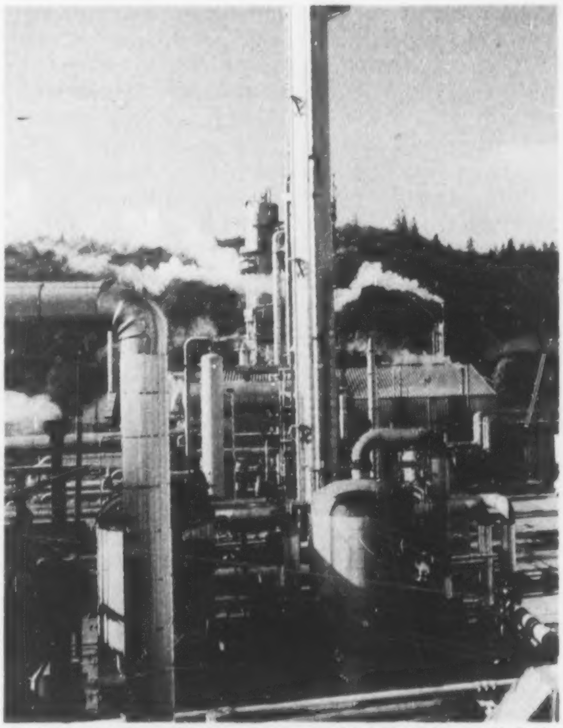
Cash-rich foreign companies continue to find U.S. industry a safe and profitable haven for investment. According to the most recent financial figures available from the U.S. government and other sources, in the past few years foreign companies have invested astoundingly high amounts of cash in the U.S. chemical industry as well as other businesses.

According to the Department of Commerce, in 1986, the most recent year for which figures are available, non-U.S. investors owned 23% of the U.S. chemical industry. That figure is based on the department's estimate of current cost net stock of fixed private capital in the chemicals and allied industries, and its report on the net book value of foreign companies' U.S. assets for those industries. For all industry, foreign investors owned 5.3% of U.S. assets.

Investment in the U.S. is apparently quite attractive. Using the Commerce figures, in 1985 foreign investors held about 20% of the U.S chemical industry. For all industry, foreign owners held 4.9%. In 1983, the stake foreign owners held in the U.S. chemical industry was only 17%, and ownership in all industry was 4.0%.

It is in part the nature of the chemical industry to operate on a global basis because of the heavy investment required in fixed assets, as well as the research and scientific expertise required to operate a chemical enterprise. U.S. chemical companies themselves owned assets abroad comparable in value to foreign chemical interests in the U.S. The Department of Commerce reports that the value of those U.S.-owned chemical interests overseas amounted to $23 billion in 1986, the same as foreign investment in the chemical industry in the U.S.

But the tide is turning as more chemical companies abroad invest in the U.S. According to James Greene, a New York City-based consultant, U.S. companies are following a pattern whereby they concentrate on one or two chemical lines and give their attention to nothing other than their highly targeted areas of expertise. Foreign companies are establishing beachheads in the U.S. to complement their worldwide businesses.



Reichhold Chemicals, now owned by Dainippon Ink & Chemicals, operates alkyd resins plant in Azusa, Calif.

Greene, who formerly followed foreign investment activity for the Conference Board, the New York City business research group, says he would guess that U.S. chemical companies' investments abroad are on an order of about half of what came into the U.S. last

Recent highlights of foreign investment activity in U.S.

1987

- Hoechst completes acquisition of Celanese Corp.
- Dainippon Ink & Chemicals completes acquisition of Reichhold Chemicals
- Mobay acquires Denka Chemical
- Courtaulds purchases Porter Paints
- Unilever acquires Chesebrough-Pond's, including Stauffer Chemical
- ICI purchases Stauffer Chemical from Chesebrough-Pond's but retains only the agricultural chemicals business
- Akzo acquires Stauffer specialty chemicals business
- Rhône-Poulenc purchases Stauffer basic chemical segment
- Henkel acquires former Diamond Shamrock's Process Chemicals Division from Occidental Petroleum
- Montedison buys remainder of Hercules interest in Himont

1986

- Air Liquide acquires Big Three Industries
- BASF acquires American Enka
- ICI purchases Glidden Paint
- Rhône-Poulenc acquires Union Carbide's Agricultural Chemicals Division
- Sandoz buys Velsicol's agrochemical business
- Dainippon Ink & Chemicals buys Sun Chemical's graphics ink unit

1985

- American Hoechst buys Hercules' interest in Hercofina
- Henkel Corp. buys 25% of Loctite's stock
- ICI buys Beatrice specialty chemical operations
- Kemira acquires American Cyanamid's Titanium Dioxide Division
- BASF acquires Celanese Carbon Fibers Division
- BASF acquires Inmont
- Ciba Geigy acquires Du Pont's pigments business

year. Still, says the consultant, who now publishes his research in a new business publication, *Northeast International Business,* a number of U.S. companies continue to expand abroad.

Examples of U.S. chemical producer investments abroad in 1987 include Arco Chemical's joint venture in South Korea with Yukong Ltd. to produce propylene oxide and styrene and another one in Indonesia with Germa Supra Abadi to make polyether polyols. Arco completed its acquisition of Atochem's polyols manufacturing facilities in Belgium, and started a joint venture with EniChem in Italy to produce resins. Du Pont signed a joint venture with DSM to make and market ethylene copolymers. FMC acquired the sodium sulfate business of Union Salinas de España in Spain, and formed a hydrogen peroxide joint venture in Thailand with Indo-Thai Synthetics.

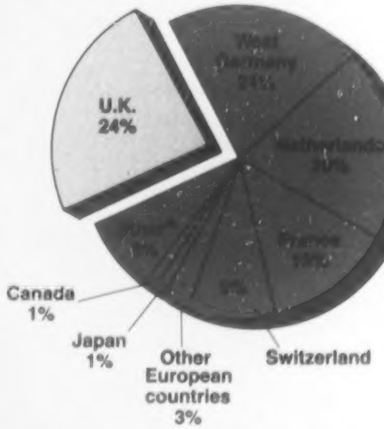
But the size of these American investments abroad last year pales in comparison with foreign-based concerns' huge investments in broad-based U.S. chemical operations for 1987. Among the larger investments in 1987 were purchase of Celanese by West Germany's Hoechst for $2.8 billion and purchase of Stauffer Chemical by Britain's ICI for $1.69 billion and its subsequent sale of two Stauffer divisions—the specialty chemicals business to Netherlands-based Akzo for $625 million and the basic chemical assets to Rhône-Poulenc, the giant French state-owned chemical company. Italian chemical giant Montedison purchased Hercules' share in the U.S.-based polypropylene producer Himont for $1.5 billion. Japan's Dainippon Ink & Chemicals completed its acquisition of Reichhold Chemicals for $600 million.

The year earlier was not a slow year either for chemical investments in the U.S. Rhône-Poulenc purchased Union Carbide's agricultural chemical business for $575 million. France's Air Liquide purchased Big Three Industries for $1.05 billion, and ICI bought the Glidden U.S. paint operations for $580 million.

Chem J. Listner, executive vice president of Findtech, the business brokerage subsidiary of Kline & Co., says that although there were more deals in which foreign companies took over U.S. chemical operations in 1986, the deals in 1987 were larger. He estimates 177 deals were completed in 1986 versus 142 in 1987, but he says that total value of those deals for 1986 and 1987 probably will be the same at $15 billion to $18 billion. The difference may indicate that large foreign players were seeking to buy more market share in 1987 than in 1986.

Industry observers believe that the large number of deals in 1986 resulted in part from the 1986 Tax Reform Act, which required taxing capital gains for the seller at ordinary tax rates beginning in 1987. Another incentive to close deals in 1986 was the tax act's repeal of a rule allowing the exchange of assets without any

U.K. is biggest foreign investor in U.S. chemicals



1986 total investment = $22.99 billion[b]

a Asia, Africa, and Latin America. b Net book value plus net outstanding loans of foreign companies to U.S. affiliates. **Source:** Department of Commerce tax consequences in certain acquisitions. But although the pace slowed in 1987, the value of all deals probably climbed last year, and that has been attributed variously to the rising specter of U.S. protectionism.

The threat of protectionism has been present for a number of years, but more recently it has come closer to reality. A trade bill now before Congress proposes to give the President authority to block foreign acquisitions of American companies if national security is believed to be threatened. In some versions, the bill also would require increased disclosure of foreign investments in American business and mandate that the U.S. retaliate against trading partners that are deemed to engage in unfair trading practices.

An analysis of the most recent government figures shows that, of all foreign investment, British-based companies collectively own the largest piece of the U.S. chemical industry, at almost 24% of the total \$23.0 billion in 1986. West German firms hold the next largest share, 21%; followed by the Netherlands, 20%; France, 13%; and Switzerland, 9.3%.

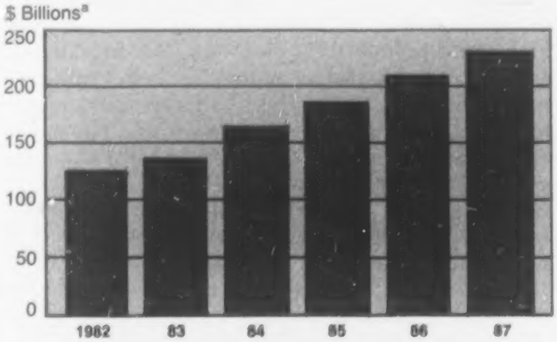
In explaining the interest of foreign investors in the U.S. and the subsequent growth of investment in this country, Alan Greenspan, chairman of the Federal Reserve Board, sees a fundamental change in the U.S. economy now under way. At a House-Senate Joint Economic Committee hearing in mid-March, Greenspan said that in the past U.S. businessmen "viewed our economy as being relatively self-contained. We thought of business cycles largely in terms of domestic spending, inventories, and production; foreign trade did not play a major role. Businesses saw their competition as being the firm down the road or in the next city or state, not the producer on the other side of the world."

More recently, Greenspan said, the U.S. economy has been driven "by external forces and is coming to resemble more nearly the open, trade-based economies of Europe than the insulated economy of our own past. We are increasingly affected by developments outside our borders."

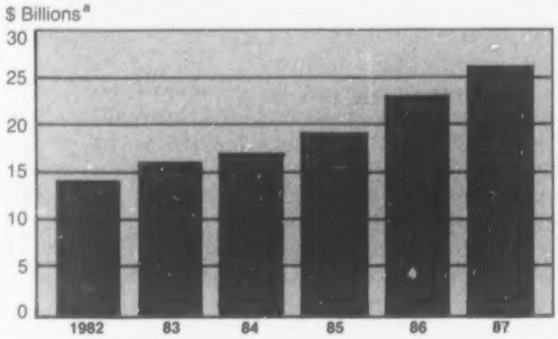
Greenspan's remarks are especially true of the chemical industry. Many major U.S. chemical producers have come to recognize that they must compete in a world economy, especially in commodity chemical lines for which there is a global demand. Commerce Department figures that show the balance of U.S. chemical industry investment abroad with foreign ownership in the U.S. chemical industry make it clear that most large U.S. producers share a global outlook of the chemical business. More significantly, the U.S. chemical industry has continually restructured itself for higher operating efficiencies and the industry as a whole has consistently shown a positive trade balance.

Given the U.S. presence abroad in the chemical industry, U.S. chemical industry executives should agree with Greenspan's open trade position. He told the Joint Economic Committee that foreign investment in the U.S. "is a highly desirable trend." From the Federal Reserve's perspective, he said that he was less concerned about the fact that more and more U.S. assets are being acquired by foreign investors than he would be if they were simply amassing U.S. dollars. Greenspan is concerned about maintaining a steady dollar relative to foreign currency, partly in an effort to allow U.S. products to compete more effectively in overseas markets to reduce U.S. debt.

Foreign ownership of all U.S. industry has nearly doubled...



...as it has for chemical industry in past five years



a Net book value plus net outstanding loans of foreign companies to U.S. affiliates.
Sources: Department of Commerce, C&EN estimates

W. Robert Clay, vice president of Du Pont's international department, says that, although foreign competitors in the chemical industry are pursuing a strategy to increase their share of the U.S. market, "we already have a substantial share here." Clay adds that Du Pont is investing in overseas markets in an effort "to get our market share worldwide to approach our share of the U.S. market." In 1987, more than 40% of Du Pont's chemical sales came from outside the U.S., says Clay. By the mid-1990s, the company expects to derive more than half its sales outside the U.S. "Sales in the U.S. are growing," says Clay, "but sales outside the U.S. are growing at a faster rate."

U.S. companies frequently complain about the constraints placed on their foreign operations by foreign governments. On the other hand, because they can often operate with a freer hand in the U.S., many foreign companies say they find the U.S. an attractive investment forum. Such problems as the repatriation of profits and the limits on ownership do not formally exist in the U.S. In addition, the enormity of the U.S. market and the political stability of the U.S. are attractions to foreign investors.

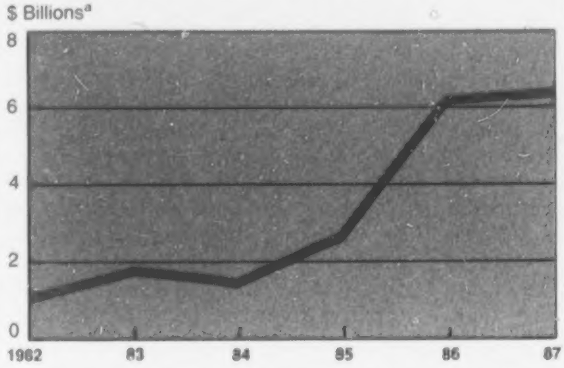
ICI, like Du Pont, believes the key to its future is in internationalizing its business. But unlike Du Pont, which could probably survive with its substantial and profitable U.S. businesses alone, ICI believes it could not in the U.K. ICI Americas chairman Harry Corless told C&EN in an interview last year when he received the International Palladium Medal of the American Section of the Société de Chimie Industrielle that ICI "couldn't survive by just concentrating its efforts on England," a country whose total economy is many times smaller than the U.S. economy.

ICI, like many international companies, believes it can invest for the long haul without concerning itself about the immediate profitability of its business. When ICI acquired Stauffer's agrochemical business, Ronnie Hampel, ICI's director responsible for American affairs, told C&EN, "We are under no illusions. The agrochemical business has been going through a difficult period. But there will always be a demand for food and the need to grow it more efficiently and well. Therefore there will be pressure on pesticide producers to provide safe and effective products."

Rhône-Poulenc president Jean-René Fourtou has expressed his interest in increasing the company's share of the U.S. chemical market. Like ICI's coup in agrochemicals, Rhône-Poulenc succeeded in springing ahead of competitors in world market share for certain organic commodities when it acquired the Stauffer basic chemicals business.

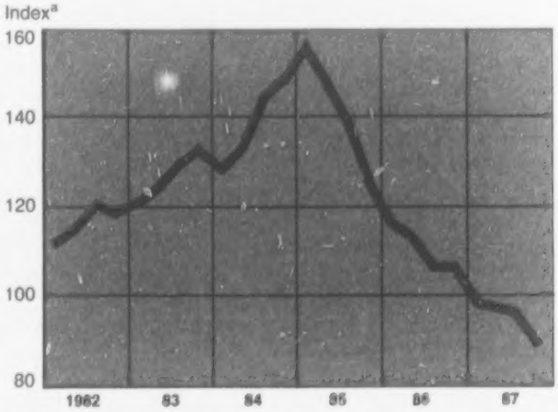
Many foreign investors are "willing to take their time to get a return on their investment," notes Grace Finley, the senior partner in Finley, McDermott & Co., an economic development consulting firm. "They're not necessarily looking for a return on a quarterly or an annual basis. Many view their acquisitions in terms of a seven- to 10-year scenario for profit, especially the Japanese, who can wait." By contrast, U.S. companies are constantly emphasizing earnings per share in response to Wall Street's emphasis on profitability, she points out.

Overseas buyers have invested heavily in U.S. chemical industry



[a] Capital and equity inflows. **Sources:** Department of Commerce, C&EN estimates

Dollar's ups and downs provide foreign investors bargain opportunities



[a] Weighted average based on exchange value of the U.S. dollar against the currencies of Belgium, Canada, France, West Germany, Italy, Japan, the Netherlands, Sweden, Switzerland, and the U.K. **Source:** Federal Reserve Board

One executive who has chalked up experience operating under both the expectations placed on a U.S. publicly owned company and a foreign publicly owned concern is Ernest H. Drew, president and chief executive officer of Hoechst Celanese. He says that "Celanese executives hoped they reacted in the past for the long-term interest, but they still looked at the short-term return. Now that pressure is off. And now our managers don't have to worry about the short term as much as they did."

Industry observers also say that currently foreign companies can invest in the U.S. more easily because the dollar is relatively cheap. Even though a cheap dollar may help fuel U.S. exports and slow the flow of imports into the U.S., it also makes U.S. assets cheaper to buy. But that line of reasoning is only one element in a decision that a foreign manufacturer must make when setting strategy for buying U.S. assets.

In 1984 and 1985, when the U.S. dollar was at its strongest, according to Federal Reserve Board figures, foreign investment in U.S. industry in general and the chemical industry in particular did not decline, but increased. As the dollar declined in 1986 and 1987, the level of foreign investment increased.

Therefore foreign investment in the U.S. obviously derives from a strategic decision to invest in the U.S. market. The foreign currency angle is another element a foreign company may play to its advantage if it is patient. A foreign company that gained a foothold in the U.S. market with imports when the dollar was strong, can now shift emphasis to U.S. manufacturing. A foreign company can then consolidate its hold on a share of the U.S. market, and at the same time export products from its U.S. plants to supply home customers just as Japanese car makers, such as Honda, are doing. □

5/4/88 A 1250-1

MAY 2, 1988

CHEMICAL & ENGINEERING

NEWS

Strategy behind Occidental's acquisition of Cain Chemical
Page 19

Dow
UNION CARBIDE
EXXON
GRACE
Shell
Kodak
AMOCO

Top 100 Chemical Producers

Page 9

0511179C098 9 K AR6618SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 18
CENEAR 66 (18) 1–64
ISSN 0009-2347

MAY 2, 1988

News of the Week

- **Earnings for the first quarter climbed substantially from the year-earlier period for many companies, a C&EN survey of 20 of the largest U.S. chemical firms shows.** **Page 6**
- **Acid rain is back in the news: atmospheric nitrate fallout has been implicated by the Environmental Defense Fund in the degradation of eastern coastal waters; the U.S. announced it wouldn't agree to a Canadian proposal for controlling nitrogen oxide emissions.** **Page 7**
- **New class of superconducting oxides that don't contain copper and that become superconducting just below 30 K has been discovered by researchers at AT&T Bell Laboratories.** **Page 7**
- **A number of chemists are among the 61 new members elected by the National Academy of Sciences at its recent annual meeting.** **Page 8**
- **Wrangling within science over favorite programs must stop and relative priorities should be established, National Academy of Sciences president Frank Press told members at the academy's annual meeting.** **Page 8**

Letters 4
Editor's Page 5

Concentrates

Business 15
Government 24
Science/Technology 28

The Departments

ACS Comment 37
People 49
Newscripts 64

Business

Sale of Cain Chemical to Occidental Petroleum will make Occidental the sixth largest U.S. chemical producer and will provide it with a few new product lines. **Page 19**

Bayer chairman Hermann Strenger wants Bayer USA sales to increase in the next five years to 25% of total corporate revenues. **Page 23**

Government

A mechanism for relative evaluation of major science initiatives by the scientific community should be set up, say speakers at a science policy colloquium. **Page 25**

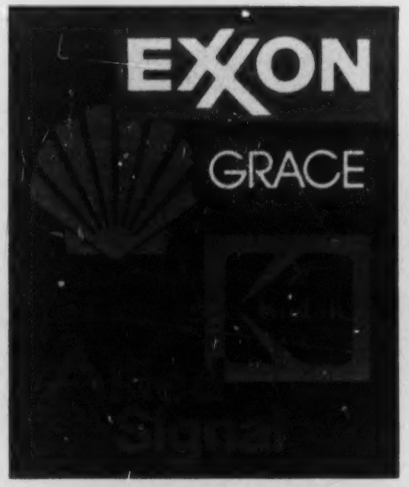
Science

Reaction rate theories are challenged by spectroscopic studies that measure precisely the product energy state distributions of the dissociation of ketene. **Page 31**

Using organosamarium complex, UC Irvine chemists insert two carbon monoxide molecules into a carbon-carbon double bond. **Page 34**

ACS News

Official reports of the ACS Board of Directors' March meeting in Washington, D.C.; light agenda expected for council's meeting in Toronto; ACS wins public relations award. **Page 40**



News Focus

Most of the 100 largest U.S. chemical producers recorded gains in sales and operating profits in 1987, indicative of the industry's robust health. **Page 9**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin

Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski

Staff Editor: Ernest L. Carpenter

Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer

Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer

Service Departments Editor: Dolores Miner

Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)

Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager** Arthur Poulos

Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 63)

LETTERS

CHEMICAL SAFETY

Sensitive sulfur nitride

SIR: It has come to our attention that a number of research groups are currently using the heterocyclic compound sulfur nitride (S_4N_4). We have worked with sulfur nitride and have performed a number of explosive sensitivity characterization tests. Results from these tests indicate sulfur nitride is an extremely sensitive, primary explosive. Sulfur nitride is more sensitive to impact and friction than is the primary explosive lead azide, commonly used in detonators.

Sensitivity to spark, however, is relatively low. The sensitivity of sulfur nitride seems to increase as a function of purity. In all these tests, decomposition was almost always extremely violent, with no explosive residue remaining. Further warnings and handling tips have been published previously [MacDairmid, A. G., "Inorganic Syntheses," Vol. 17, Robert E. Krieger Publishing Co., Melbourne, Fla., page 197 (1977)]. Thus, sulfur nitride should be considered a sensitive, primary explosive and handled with appropriate caution.

Gregory A. Buntain
Los Alamos National Laboratory

Editor's note: Additional references are: Kaye, S. M., editor, "Encyclopedia of Explosives and Related Items," Vol. 8, U.S. Army Armament Research & Development Command, Large-Caliber Weapon Systems Laboratory, Dover, N.J. (1978); and Sax, N. I., Feiner, B., "Dangerous Properties of Industrial Materials," 6th Ed., Van Nostrand Reinhold, New York, page 2491 (1984).

Plastic handguns

SIR: Alan Nixon's letter (C&EN, March 7, page 4) suggesting that ACS go on record as opposing so-called "plastic handguns" is certainly inappropriate as well as highly misleading.

First, handguns that can pass undetected through an x-ray screen simply do not exist. All firearms and cartridges contain metal. This entire plastic gun issue is merely a tactic of antigun fanatics who wish to instill their paranoia in the public in order to achieve their misguided goals. Sen. Howard Metzenbaum has been attempting to pass a plastic gun bill that effectively bans many existing small caliber weapons that are made of metal and are certainly not invisible to either metal detectors or x-ray examination. This issue is simply a misrepresentation meant to delude us into accepting further repressive legislation. The airport security problem that this bill purports to address is not one of imaginary threats but one of inadequate manpower, insufficient training, and holes in the security systems. This has been demonstrated all too often. Terrorists or the otherwise imbalanced do not need to be concerned with the detectability of their weapons because they find ways to circumvent the airport security.

Second, while I agree that it is appropriate for ACS to get involved in political issues, this should be limited to those issues that the membership as a whole has a common interest in. I do not feel that C&EN should be a medium for the discussion of every controversial topic that comes along. If this is allowed to happen this newsmagazine will become valueless as a forum of chemistry and industry interests.

John L. Krstenansky
Cincinnati

Genome mapping project

SIR: The real question on the genome mapping project (C&EN, March 14, page 22) is not James Watson's "How will it be managed?" but, rather, the question raised by David Baltimore's criticism: that the project "seems a ploy to raise money, a project justified by its public relations value, not its scientific value."

Will someone please make an adequate attempt to address this question? I mean the arguments that genome mapping is happening already (so, too, gene sequencing), that technology development is happening already, that genome databases, networking, and coordination among researchers are happening already. What, precisely, is the necessity or, anyways, the justification for this massive project?

The reporting on why a majority of the project's critics became converts has not been adequate. In all reports, including yours, we are told that the shift in focus (or at least, language) from sequencing to mapping was the key to the consensus position; the two strategies' main differences being time and money. Yet you report that as a result of this shift, instead of a "$3 billion project" requiring "thousands of hours of labor" (sequencing the entire genome), the scientists have agreed to a much more manageable "$200 million per year for about 15 years." Sorry, but I neither get it nor buy it.

Joyce Gramza
Brooklyn, N.Y.

Sales, Profits Rise for Most Top 100 Chemical Producers

Of 100 largest companies, 91 registered sales gains and 83 had higher profits in 1987, reflecting continuing health of U.S. chemical industry

William J. Storck, C&EN New York

The U.S. chemical industry enjoyed a robust year in 1987, and C&EN's compilation of financial results for the 100 largest chemical producers in the U.S. reflects this health. Sales were up for almost all the firms, and chemical operating profits improved dramatically for a majority of those that report such figures.

Nonetheless, restructuring within the industry forced some shifting in rank among the 100 from the previous year's rank, and it caused the addition or deletion of a handful of companies.

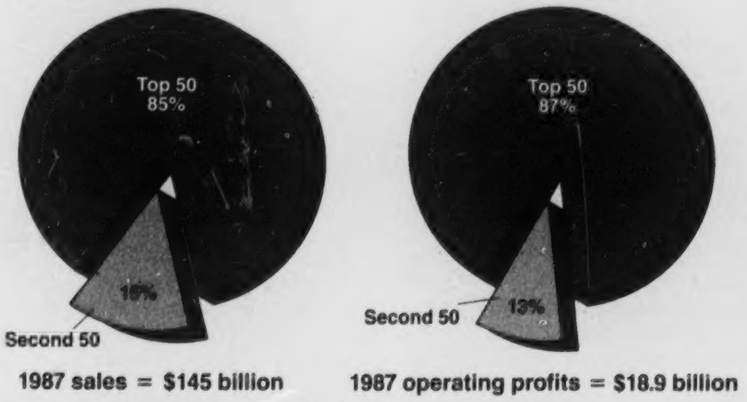
The ranking of the Top 100 chemical producers is based on chemical sales as reported in corporate annual reports and, in the case of companies not issuing annual reports, interviews with the companies.

As in the past many years, Du Pont once again has captured the top spot as the largest chemical producer in the U.S. Although it technically is a diversified company with less than half its total sales in chemicals, Du Pont amassed chemical sales totaling $13.1 billion last year, about $2.3 billion more than its nearest-ranking competitor, Dow Chemical. Indeed, that the five largest chemical producers—Du Pont, Dow Chemical, Exxon, Union Carbide, and Monsanto—all held their same ranking as the year before is a testament to their size and stability.

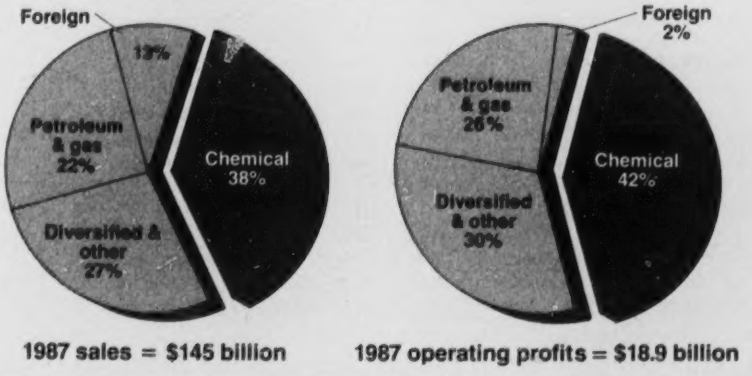
Of the 100 chemical producers, 91 posted sales gains, and only seven posted declines. For the remaining two, Avery Inc. and Cain Chemical, any comparison with 1986 's meaningless or impossible. Avery (ranked 66th), which purchased Uniroyal's chemical operations and now has put them up for sale again, had no chemical sales before the acquisition. And Cain Chemical (ranked 80th) did not exist before April 8, 1987. Cain probably would have ranked much higher had its sales been reported for a full 12-month period as for all the other companies; instead its sales are only for the period between its inception and the end of its fiscal year on Sept. 30. Considering the acquisition of Cain by Occidental Petroleum (see page 19), this year and possibly next year may mark the only appearances of Cain on the Top 100 listing.

Of the seven companies whose

Large firms have biggest share of chemical sales and earnings...



...and chemical companies sell more and earn more from chemical operations



Note: Based on sales and operating profits for Top 100 chemical producers.

Some Top 100 sales rankings changed dramatically in 1987

Rank 1987	Rank 1986		Chemical sales 1987 ($ millions)	Change from 1986	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1986	Chemical operating profits as % of total	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
1	1	**Du Pont**	$13,051	10.2%	42.8%	Diversified	$2314	31.2%	57.7%	17.7%	$9265	36.9%	25.0%
2	2	**Dow Chemical**	10,847	22.4	81.1	Basic chemicals	1930	97.3	84.2	17.8	9379	65.3	20.6
3	3	**Exxon**	7,177	18.1	8.7	Petroleum	1087	33.0	14.2	15.1	6285	8.5	17.3
4	4	**Union Carbide**	6,177[d]	23.5	89.3	Basic chemicals	872	16.6	97.4	14.1	6219	78.8	14.0
5	5	**Monsanto**	5,163	9.8	67.6	Basic chemicals	766	−14.5	104.4	14.8	3995	47.3	19.2
6	29	**Hoechst Celanese**	4,284	221.9	93.2	Basic chemicals	na	na	na	na	na	na	na
7	6	**BASF**	3,816	14.3	86.0	Basic chemicals	na	na	na	na	na	na	na
8	7	**Shell Oil**	3,578	8.7	17.2	Petroleum	600	−7.4	29.8	16.8	3681	13.7	16.3
9	8	**Amoco**	3,494	19.3	15.6	Petroleum	704	50.7	25.4	20.1	2689	10.8	26.2
10	16	**Occidental Petroleum**	2,991	43.2	16.9	Petroleum	398	126.7	51.6	13.3	2471	14.8	16.1
11	12	**Mobil**	2,926	22.4	5.2	Petroleum	433	111.2	10.2	14.8	2316	5.6	18.7
12	10	**Allied-Signal**	2,795	−0.9	25.1	Diversified	306	−11.6	40.8	10.9	2043	20.0	15.0
13	11	**W. R. Grace**	2,794	12.1	61.9	Specialty chemicals	357	25.3	81.5	12.8	1960	43.8	18.2
14	15	**General Electric**	2,751[d]	18.0	6.8	Diversified	507	19.6	11.4	18.4	3891	10.0	13.0
15	13	**Eastman Kodak**	2,600	9.3	19.5	Photo equipment	388	70.9	18.4	14.9	2514	17.4	15.4
16	14	**Chevron**	2,593	9.0	9.2	Petroleum	397	170.1	12.0	15.3	1754	5.1	22.6
17	17	**Rohm & Haas**	2,203	6.6	100.0	Basic chemicals	323	15.4	100.0	14.7	1587	81.2	20.4
18	18	**Atlantic Richfield**	1,967	3.1	11.7	Petroleum	379	166.8	31.0	19.3	2513	11.1	15.1
19	19	**American Cyanamid**	1,960	7.6	47.1	Basic chemicals	193	43.3	41.3	9.8	1387	33.6	13.9
20	—	**Arco Chemical**	1,952	26.7	100.0	Basic chemicals	398	63.1	100.0	20.4	1746	68.9	22.8
21	23	**Phillips Petroleum**	1,928	13.5	18.0	Petroleum	482	61.2	44.2	25.0	1165	9.6	41.4
22	20	**Air Products[e]**	1,919	6.8	89.2	Basic chemicals	373	2.8	116.7	19.4	2311	85.5	16.1
23	33	**Quantum Chemical**	1,875	72.6	73.1	Basic chemicals	348	180.5	91.5	18.5	1483	57.5	23.4
24	24	**Borden**	1,857	13.4	28.5	Dairy products	208	18.2	33.9	11.2	1121	27.0	18.6
25	21	**Bayer USA**	1,800	5.3	42.9	Basic chemicals	84[f]	0	68.3	4.7	na	na	na
26	27	**B. F. Goodrich**	1,741	19.4	80.3	Rubber products	210	57.3	92.1	12.1	1280	66.0	16.4
27	22	**Hercules**	1,686	−1.3	62.6	Basic chemicals	134	32.7	64.4	7.9	1318	37.7	10.2
28	26	**Ashland Oil**	1,643	11.2	22.9	Petroleum	90	26.8	33.6	5.5	603	14.9	14.9
29	25	**Ciba-Geigy**	1,620	8.7	57.4	Specialty chemicals	na	na	na	na	na	na	na
30	30	**Texaco**	1,587	24.1	4.6	Petroleum	129	41.6	1.9	8.1	1182	3.5	10.9
31	28	**FMC**	1,488	6.4	48.0	Machinery	242	8.0	69.6	16.3	1335	51.5	18.1
32	31	**Ethyl**	1,406	10.5	54.5	Basic chemicals	258	4.2	65.8	18.3	1018	51.4	25.3
33	34	**Dow Corning**	1,303	20.1	100.0	Specialty chemicals	135[f]	22.1	100.0	10.4	na	na	na
34	72	**Rhône-Poulenc**	1,300	242.1	100.0	Specialty chemicals	na	na	na	na	na	na	na
35	32	**Olin**	1,232	10.6	63.8	Basic chemicals	99	24.1	66.4	8.0	924	54.8	10.7
36	35	**International Minerals[g]**	1,214	12.7	74.1	Agrochemicals	104	197.4	58.8	8.5	1769	72.7	5.9
37	36	**National Starch**	1,208	13.6	100.0	Specialty chemicals	175	25.0	100.0	14.5	941	100.0	18.6
38	37	**Unocal**	1,071	1.4	11.4	Petroleum	27	−41.3	14.9	2.5	648	6.4	4.2
39	58	**Huntsman Chemical**	1,022	79.3	100.0	Basic chemicals	na	na	na	na	na	na	na
40	41	**Aluminum Co. of America**	982[d]	16.9	12.6	Nonferrous metals	63	284.0	9.2	6.4	2444	24.7	2.6
41	40	**PPG Industries**	953	13.0	18.4	Glass Products	140	35.9	18.0	14.7	1019	20.4	13.7
42	—	**BP America**	943	48.5	6.1	Petroleum	32	−38.5	1.4	3.4	na	na	na
43	39	**Lubrizol**	940	5.7	91.9	Specialty chemicals	140	−0.1	110.5	14.8	649	69.1	21.5
44	46	**Aristech**	919	22.4	100.0	Basic chemicals	120	23.1	100.0	13.1	na	na	na
45	74	**Freeport-McMoRan**	860	129.8	56.8	Agrochemicals	106	40.8	33.5	12.4	714	22.6	14.9
46	48	**NL Industries**	859	17.1	62.7	Petroleum services	209	23.5	140.7	24.4	734	56.3	28.5
47	42	**Pennwalt**	846	8.9	74.1	Basic chemicals	103	10.6	74.4	12.2	716	68.7	14.4
48	47	**Nalco Chemical**	842	14.4	100.0	Specialty chemicals	131	21.2	100.0	15.6	747	100.0	17.5
49	44	**Reichhold Chemicals**	837	9.3	100.0	Basic chemicals	na	na	na	na	na	na	na
50	44	**CF Industries**	810	5.7	100.0	Agrochemicals	4	def	100.0	0.5	856	100.0	0.5

Rank 1987	Rank 1986		Chemical sales 1987 ($ millions)	Change from 1986	Chemical sales as % of total sales	Industry classification	Chemical operating profits[a] ($ millions)	Change from 1986	Chemical operating profits as % of total	Operating profit margin[b]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[c]
51	43	**Cabot**[e]	$ 800	4.1%	56.2%	Specialty metals	$ 122	−11.2%	92.3%	15.3%	$ 563	38.5%	21.7%
52	49	**Eli Lilly**	748	7.1	20.5	Drugs	85	60.2	8.8	11.3	724	13.8	11.7
53	53	**International Flavors**	746	20.2	100.0	Specialty chemicals	184	27.2	100.0	24.6	665	76.1	27.6
54	51	**Morton Thiokol**[g]	744	14.2	37.5	Diversified	130	48.5	50.0	17.4	698	41.9	18.6
55	62	**Polysar**	720	34.5	100.0	Basic chemicals	na	na	na	na	na	na	na
56	50	**Engelhard**	712	7.0	28.7	Specialty metals	87	13.5	83.2	12.3	677	55.6	12.9
57	56	**Georgia Gulf**	707	21.3	100.0	Basic chemicals	163	125.0	100.0	23.0	309	100.0	52.7
58	59	**Solvay America**	700[d]	27.3	100.0	Basic chemicals	na	na	na	na	na	na	na
59	52	**Terra Chemicals**	679	8.5	100.0	Agrochemicals	na	na	na	na	na	na	na
60	69	**American Petrofina**	6[illegible]0	51.9	27.0	Petroleum	203	282.3	126.6	30.3	280	15.3	72.5
61	55	**Koppers**	662	12.4	43.7	Diversified	31	−20.8	22.5	4.7	na	na	na
62	61	**Witco**	624[h]	14.6	43.7	Specialty chemicals	61	35.6	49.9	9.7	332	31.5	18.2
63	59	**Vista Chemical**[e]	609	10.7	100.0	Basic chemicals	119	31.2	100.0	19.6	500	100.0	23.8
64	83	**Henkel**	600	126.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
65	63	**H. B. Fuller**[i]	597	13.0	100.0	Specialty chemicals	48	20.9	100.0	8.0	330	100.0	14.5
66	—	**Avery**[e]	591	nm	98.4	Agrochemicals	na	na	na	na	na	na	na
67	57	**Farmland Industries**	525	−8.6	20.1	Agricultural supplies	1	def	1.7	0.2	316	40.1	0.4
68	70	**Pfizer**	514	23.6	10.4	Drugs	70	71.4	6.6	13.6	483	7.0	14.4
69	64	**Liquid Air**	505	2.8	89.8	Basic chemicals	68	15.7	96.9	13.6	610	81.2	11.2
70	68	**CBI Industries**	492	9.1	42.4	Construction	68	12.5	82.3	13.7	612	48.3	11.1
71	80	**Great Lakes Chemical**	478	59.3	100.0	Specialty chemicals	85	99.1	100.0	17.8	577	100.0	14.7
72	66	**Henley Manufacturing**	464	1.9	76.7	Basic chemicals	39	25.0	101.9	8.5	372	54.2	10.6
72	66	**Kerr-McGee**	464	1.8	17.8	Petroleum	71	9.2	13.7	15.3	549	19.0	12.9
74	71	**Tyler**	436	12.4	39.6	Diversified chemicals	37	35.3	55.5	8.4	203	37.4	18.0
75	73	**GAF**	431	14.3	51.5	Specialty chemicals	130	20.6	82.5	30.1	420	32.3	31.0
76	75	**Merck**	431	20.1	8.5	Drugs	58	15.4	4.2	13.4	429	7.6	13.4
77	76	**Betz Laboratories**	386	12.0	100.0	Specialty chemicals	68	6.8	100.0	17.5	287	100.0	23.6
78	77	**Sun Co.**	371	17.0	3.9	Petroleum	na	na	na	na	na	na	na
79	81	**Ferro**	362[d]	26.9	41.6	Specialty materials	28	25.7	39.0	7.7	187	35.1	14.9
80	—	**Cain Chemical**[j]	357	nm	100.0	Basic chemicals	na	na	na	na	na	na	na
81	79	**Union Camp**	348	14.3	15.1	Diversified	21	236.9	5.6	6.0	279	9.6	7.5
82	82	**Loctite**	338	26.6	100.0	Specialty chemicals	45	23.3	100.0	13.4	297	97.8	15.3
83	78	**Chemed**	336	6.9	85.9	Specialty chemicals	41	25.4	84.5	12.3	177	67.1	23.3
84	88	**Lonza**	312	23.8	100.0	Specialty chemicals	na	na	na	na	na	na	na
85	85	**Vulcan Materials**	298	17.4	32.2	Nonmetallic minerals	33	68.6	17.9	11.0	na	na	na
86	84	**Stepan**	289	11.2	100.0	Specialty chemicals	119	751.6	620.0	41.3	173	100.0	69.0
87	89	**Dexter**	285	16.5	36.4	Rubber products	29	25.4	30.3	10.3	182	61.9	16.1
88	85	**Petrolite**[k]	248	−2.2	89.1	Specialty chemicals	21	−6.2	99.2	8.6	181	73.0	11.8
89	91	**Sigma-Aldrich**	247	24.1	81.2	Specialty chemicals	64	21.1	88.2	25.8	246	86.1	25.9
90	85	**KaiserTech**	239	−5.9	10.8	Nonferrous metals	16	−51.8	def	6.8	na	na	na
91	92	**Essex Chemical**	191	3.8	91.4	Basic chemicals	28	−13.3	172.9	14.5	143	64.2	19.3
92	93	**Crompton & Knowles**	191	15.8	80.3	Specialty chemicals	20	33.1	70.7	10.4	98	72.3	20.2
93	94	**Georgia-Pacific**	189	21.9	3.3	Wood products	na	na	na	na	na	na	na
94	95	**First Mississippi**	181	18.5	61.2	Agrochemicals	8	−59.6	80.9	4.4	81	27.4	9.9
95	90	**Mississippi Chemical**[g]	174	−23.5	101.8	Farm cooperative	−26	def	def	def	230	100.0	def
96	97	**Quaker Chemical**	148	15.2	100.0	Specialty chemicals	17	21.6	100.0	11.4	118	100.0	14.2
97	96	**Agway**	133	−6.4	4.1	Farm cooperative	na	na	na	na	na	na	na
98	99	**LeaRonal**[l]	126	21.6	100.0	Specialty chemicals	13	21.2	100.0	9.8	75	96.3	16.8
99	98	**UGI**	116	2.9	27.6	Natural gas	1	def	2.5	1.3	61	10.2	2.4
100	100	**Lawter Chemicals**	112	8.2	100.0	Specialty chemicals	25	24.6	100.0	21.9	110	100.0	22.3

a Operating profit is sales less administrative expenses and cost of sales. b Operating profit from chemicals as a percentage of chemical sales. c Chemical operating profit as a percentage of identifiable chemical assets. d Chemical sales include significant amounts of nonchemical products. e Fiscal year ends Sept. 30. f Chemical net income. g Fiscal year ends June 30. h Does not include all chemical sales. i Fiscal year ends Nov. 30. j Sales are only for the period between formation of the company April 8, 1987, and end of fiscal year Sept. 30. k Fiscal year ends Oct. 31. l For fiscal year ended Feb. 28, 1987. na = not available. nm = not meaningful. def = deficit.

C&EN's five-way ranking of the Top 100 chemical producers

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1987	1987	1986	1987	1987	1986	1987	1987	1986	1987	1987	1986	1987	1987	1986
Agway	$ 133	97	98	na	—	—	na	—	—	na	—	—	na	—	—
Air Products	1,919	22	20	$ 373	16	9	19.4%	13	5	$2311	14	13	16.1%	38	27
Allied-Signal	2,795	12	10	306	20	10	10.9	56	37	2043	15	14	15.0	44	30
Aluminum Co. of America	982	40	41	63	58	76	6.4	73	82	2444	12	11	2.6	72	76
American Cyanamid	1,960	19	19	193	27	29	9.8	60	65	1387	22	25	13.9	54	56
American Petrofina	670	60	69	203	26	52	30.3	2	39	280	61	64	72.5	1	16
Amoco	3,494	9	8	704	6	7	20.1	11	18	2689	8	9	26.2	8	25
Arco Chemical	1,952	20	—	398	11	na	20.4	10	—	1746	29	24	22.8	15	—
Aristech	919	44	46	120	40	37	13.1	45	34	na	—	—	na	—	—
Ashland Oil	1,643	28	26	90	47	47	5.5	75	77	603	46	47	14.9	45	44
Atlantic Richfield	1,967	18	18	379	15	25	19.3	14	65	2513	10	18	15.1	43	61
Avery	591	66	—	na	—	—	na	—	—	na	—	—	na	—	—
BASF	3,816	7	6	na	—	—	na	—	—	na	—	—	na	—	—
BP America	943	42	—	32	67	na	3.4	79	—	na	—	—	na	—	—
Bayer USA	1,800	25	21	84	51	42	4.7	76	76	na	—	—	na	—	—
Betz Laboratories	386	77	76	68	54	49	17.5	21	11	287	60	60	23.6	12	14
Borden	1,857	24	24	208	25	19	11.2	54	47	1121	28	21	18.6	26	46
CBI Industries	492	70	68	68	54	50	13.7	39	31	612	44	44	11.1	63	55
CF Industries	810	50	44	4	81	86	0.5	82	—	856	33	30	0.5	74	—
Cabot	800	51	43	122	39	28	15.3	26	13	563	48	48	21.7	18	8
Cain Chemical	357	80	—	na	—	—	na	—	—	na	—	—	na	—	—
Chemed	336	83	78	41	63	66	12.3	46	48	177	69	71	23.3	14	18
Chevron	2,593	16	14	397	13	23	15.3	26	73	1754	18	8	22.6	16	72
Ciba-Geigy	1,620	29	25	na	—	—	na	—	—	na	—	—	na	—	—
Crompton & Knowles	191	91	93	20	76	77	10.4	57	55	98	74	78	20.2	22	31
Dexter	285	87	89	29	69	70	10.3	59	53	182	67	71	16.1	38	38
Dow Chemical	10,847	2	2	1930	2	2	17.8	18	45	9379	1	2	20.6	20	47
Dow Corning	1,303	33	34	135	33	32	10.4	57	49	na	—	—	na	—	—
Du Pont	13,051	1	1	2314	1	1	17.7	20	21	9265	2	1	25.0	11	19
Eastman Kodak	2,600	15	13	388	14	16	14.9	30	52	2514	9	12	15.4	41	57
Eli Lilly	748	52	49	85	49	52	11.3	53	63	724	36	33	11.7	61	69
Engelhard	712	56	50	87	48	44	12.3	48	42	677	40	37	12.9	58	45
Essex Chemical	191	91	92	28	70	67	14.5	36	15	143	71	76	19.3	23	3
Ethyl	1,406	32	31	258	21	15	18.3	17	8	1018	30	32	25.3	10	5
Exxon	7,177	3	3	1087	3	4	15.1	29	29	6285	3	3	17.3	34	35
FMC	1,488	31	28	242	22	17	16.3	24	17	1335	23	23	18.1	31	27
Farmland Industries	525	67	57	1	82	85	0.2	83	—	316	57	55	0.4	75	—
Ferro	362	79	81	28	70	72	7.7	71	61	187	66	71	14.9	45	42
First Mississippi	181	94	95	8	80	73	4.4	78	34	81	75	80	9.9	68	6
Freeport-McMoRan	860	45	74	106	43	45	12.4	47	5	714	38	65	14.9	45	2
H. B. Fuller	597	65	63	48	61	62	8.0	68	64	330	56	57	14.5	49	43
GAF	431	75	73	130	36	33	30.1	3	1	420	53	63	31.0	5	1
General Electric	2,751	14	15	507	8	8	18.4	16	12	3891	6	6	13.0	57	50
Georgia Gulf	707	57	56	163	30	46	23.0	8	36	309	58	61	52.7	3	9
Georgia-Pacific	189	93	94	na	—	—	na	—	—	na	—	—	na	—	—
B. F. Goodrich	1,741	26	27	210	23	30	12.1	51	54	1280	25	26	16.4	36	54
W. R. Grace	2,794	13	11	357	17	12	12.8	46	43	1960	16	17	18.2	29	28
Great Lakes Chemical	478	71	80	85	49	59	17.8	18	25	577	47	na	14.7	48	—
Henkel	600	64	83	na	—	—	na	—	—	na	—	—	na	—	—
Henley Manufacturing	464	72	66	39	64	67	8.5	64	71	372	54	53	10.8	66	65

	Chemical sales			Chemical operating profits			Chemical operating profit margin			Identifiable chemical assets			Return on chemical assets		
		Rank			Rank			Rank			Rank			Rank	
$ Millions	1987	1987	1986	1987	1987	1986	1987	1987	1986	1987	1987	1986	1987	1987	1986
Hercules	$1,686	27	22	$ 134	34	36	7.9%	70	74	$1318	24	20	10.2%	67	69
Hoechst Celanese	4,264	6	29	na	—	—	na	—	—	na	—	—	na	—	—
Huntsman Chemical	1,022	39	58	na	—	—	na	—	—	na	—	—	na	—	—
International Flavors	746	53	53	184	28	24	24.6	6	3	665	41	46	27.6	7	11
International Minerals	1,214	36	35	104	44	64	8.5	64	79	1769	17	16	5.9	70	75
KaiserTech	239	90	85	16	78	65	6.8	72	31	na	—	58	na	—	48
Kerr-McGee	464	72	66	71	52	48	15.3	26	24	549	49	45	12.9	58	48
Koppers	662	61	55	31	68	61	4.7	76	72	na	—	55	na	—	51
Lawter Chemicals	112	100	100	25	73	73	21.9	9	10	110	73	79	22.3	17	17
LeaRonal	128	98	99	13	79	81	9.8	60	50	75	76	81	16.8	35	31
Liquid Air	505	69	64	68	54	51	13.6	40	39	610	45	38	11.2	62	58
Loctite	338	82	82	45	62	63	13.4	42	27	297	59	65	15.3	42	33
Lonza	312	84	88	na	—	—	na	—	—	na	—	—	na	—	—
Lubrizol	940	43	39	140	31	26	14.8	31	19	649	42	39	21.5	19	13
Merck	431	75	75	58	60	56	13.4	42	26	429	52	52	13.4	56	51
Mississippi Chemical	174	95	90	−26	84	84	def	—	—	230	64	61	def	—	—
Mobil	2,926	11	12	433	10	18	14.8	31	58	2316	13	15	18.7	25	59
Monsanto	5,163	5	5	766	5	3	14.8	31	9	3995	5	5	19.2	24	15
Morton Thiokol	744	54	51	130	36	41	17.4	22	29	698	39	41	18.6	26	33
NL Industries	859	46	48	209	24	21	24.4	7	4	734	35	43	28.5	6	3
Nalco Chemical	842	48	47	131	35	33	15.6	25	23	747	34	40	17.5	33	24
National Starch	1,208	37	36	175	29	26	14.5	36	33	941	31	34	18.6	26	21
Occidental Petroleum	2,991	10	16	398	11	19	13.3	44	59	2471	11	10	16.1	38	68
Olin	1,232	35	32	99	46	43	8.0	68	67	924	32	31	10.7	65	60
PPG Industries	953	41	40	140	31	35	14.7	34	38	1019	29	27	13.7	55	66
Pennwalt	846	47	42	103	45	38	12.2	50	39	716	37	36	14.4	50	40
Petrolite	246	88	85	21	74	70	8.6	63	55	181	68	74	11.8	60	38
Pfizer	514	68	70	70	53	60	13.6	40	50	483	51	51	14.4	50	62
Phillips Petroleum	1,928	21	23	482	9	11	25.0	5	14	1165	27	29	41.4	4	7
Polysar	720	55	62	na	—	—	na	—	—	na	—	—	na	—	—
Quaker Chemical	148	96	97	17	77	78	11.4	52	46	118	72	77	14.2	52	41
Quantum Chemical	1,875	23	33	348	18	31	18.5	15	43	1483	21	22	23.4	13	64
Reichhold Chemicals	837	49	44	na	—	52	na	—	69	na	—	50	na	—	51
Rhône-Poulenc	1,300	34	72	na	—	—	na	—	—	na	—	—	na	—	—
Rohm & Haas	2,203	17	17	323	19	13	14.7	34	28	1587	20	19	20.4	21	20
Shell Oil	3,578	8	7	600	7	6	16.8	23	7	3681	7	7	16.3	37	22
Sigma-Aldrich	247	89	91	64	57	52	25.8	4	2	246	63	68	25.9	9	12
Solvay America	700	58	59	na	—	—	na	—	—	na	—	—	na	—	—
Stepan	289	86	84	119	41	78	41.3	1	75	173	70	75	69.0	2	62
Sun Co.	371	78	77	na	—	—	na	—	—	na	—	—	na	—	—
Terra Chemicals	679	59	52	na	—	—	na	—	—	na	—	—	na	—	—
Texaco	1,587	30	30	129	38	39	8.1	67	68	1182	26	28	10.9	64	67
Tyler	436	74	71	37	65	69	8.4	66	69	203	65	69	18.0	32	37
UGI	116	99	98	1	82	83	1.3	81	—	61	77	70	2.4	73	—
Union Camp	348	81	79	21	74	82	6.0	74	81	279	62	67	7.5	69	74
Union Carbide	6,177	4	4	872	4	5	14.1	38	20	6219	4	4	14.0	63	35
Unocal	1,071	38	37	27	72	57	2.5	80	78	648	43	35	4.2	71	71
Vista Chemical	609	63	59	119	41	39	19.6	12	16	500	50	49	na	—	23
Vulcan Materials	298	35	85	33	66	75	11.0	55	62	na	—	—	na	—	—
Witco	624	62	61	61	59	58	9.7	62	60	332	55	59	18.2	29	29

Note: Companies with negative profitability are not ranked. na = not available. def = deficit.

sales declined, three are in the troubled fertilizer industry—Agway, Mississippi Chemical, and Farmland Industries. The other four are Allied-Signal, Hercules, Petrolite, and KaiserTech.

Eighty-four companies in the group reported information on chemical operating profits, and only one of them, Mississippi Chemical, showed a loss for the year. However, 12 posted declines in earnings from the previous year.

The larger firms continue to dominate the Top 100, as do companies whose primary business is chemicals. In 1987, the 50 largest chemical producers accounted for 85% of the total sales of the 100 companies and 87% of the operating profits. This is a slight decline from the year before, when the largest 50 companies accounted for 86% of total sales and 90% of operating profits.

Companies whose largest business is chemicals also continue to account for more of the financial results than do other categories. In 1987, chemical companies contributed 38% of the total sales of the 100 companies and 42% of total operating profits. These percentages were the same as in last year's listing.

Petroleum and natural gas-producing firms made up 22% of sales and 26% of operating profits. Here sales were down from 25% in 1986, but the share of earnings was up from 24%. Diversified companies contributed 27% of sales last year, down slightly from 28% in 1986, and their earnings contribution fell to 30% from 32% the year before.

Foreign-owned chemical producers, most of which could be counted as chemical companies, contributed 13% of total sales in 1987, compared with just 9% in 1986. Earnings contributions from the overseas-owned companies were 2% in both years. The very low earnings contributions by the foreign-owned firms stem not from poor results, but rather from the fact that so few of them report chemical profits. Undoubtedly, if the same percentage of these companies reported their profits as did their counterparts in other categories, their contribution to earnings would fall more in line with their sales contribution.

In 1987, as in past years, industry restructuring played a large role in shaping the rankings. Besides Avery and Cain, there were two other companies new to the listing this year. Arco Chemical ranked 20th after it was formed by a spinoff of some of Atlantic Richfield's chemical operations. Atlantic Richfield remains on the list because of its retained chemical businesses. The other new company is BP America, in the 42nd spot. BP, although it long has had chemical operations in the U.S., had not reported its results until acquiring Standard Oil. As a result, Standard Oil has been dropped from the list.

Other companies no longer ranked include Borg Warner, which has "gone private" and no longer discloses chemical results; Williams Cos., which sold its Agrico fertilizer operations to Freeport McMoRan Partners; and Celanese, which was acquired by Hoechst.

The acquisition of Celanese by Hoechst caused one of the largest jumps in the rankings for 1987. The combined company—Hoechst Celanese—gained the ranking of 6th, up from 29th in 1986 when the firm was known as American Hoechst. However, Celanese was 10th in the 1986 ranking.

Although the Hoechst Celanese combination was the largest dollar move among the Top 100, its ranking jump of 23 places was not the greatest. That distinction goes to Rhône-Poulenc, which climbed 38 spots to end up as 34th, compared with its rank of 72nd in 1986. The French-owned company gained its position on the strength of purchasing Union Carbide's agricultural chemicals business and the Stauffer basic chemical business from ICI.

Also upgrading its rank more than Hoechst Celanese was Freeport-McMoRan, which jumped 29 places to 45th after placing only 74th in the 1986 ranking. Two other companies improved their rankings by 19 places. Huntsman Chemical moved to the 39th spot in 1987 from 58th in 1986. And Henkel climbed to 64th from 83rd the year before.

All in all, of the 100 companies, 30 improved in rank in 1987 from the year before, 51 declined in rank, and 15 held the same position. Four companies were new to the list.

As in past years, companies in the 1987 list are compared with what their rankings actually were one year ago, rather than what they would have been had the previous year's results been restated for divestitures, acquisitions, or other corporate developments. Thus, a rise or fall in rank will reflect these developments as well as any normal increase or decrease from operations.

Other factors can influence the rankings. For instance, in the case of some foreign companies, currency translations from year to year can change results from what the company actually states. This may be why, for C&EN's calculations, Lonza shows a 24% increase in sales, whereas the U.S. arm of the Swiss-owned company claims only a 13% increase in sales for the year. Again, where possible, C&EN tries to calculate changes in results from the previous year's figures rather than from figures that may have been restated in the current year.

Admittedly, the C&EN ranking does not include all U.S. chemical operations that could be on it. In many cases, for one reason or another, companies will not disclose their chemical sales. For instance, Borg Warner still has its chemical operations, dominated by acrylonitrile-butadiene-styrene, but since it is now in private hands it does not disclose its chemical sales. Others that would surely make the list include 3M and such foreign-owned firms as Britain's ICI Americas and West Germany's Sherex.

Besides chemical sales, C&EN also ranks the companies according to chemical operating profits, chemical operating profit margins, identifiable chemical assets, and return on chemical assets (chemical operating profits as a percentage of identifiable chemical assets). As in sales, Du Pont ranked number one in chemical operating profits in 1987 with a total of $2.31 billion. However, Dow Chemical beat out Du Pont in chemical assets with a total of $9.38 billion. In terms of profitability, Stepan ranked number one in operating profit margin at 41%. And American Petrofina had the best return on chemical assets at a whopping 73%. □

Priority-Setting Urged in Funding of Major Science Initiatives

In light of federal budget constraints, mechanism is needed for reaching consensus in scientific community on which large projects to fund

Janice R. Long, C&EN Washington

Policy makers for years have been urging the scientific community to become involved in setting priorities for federal research funding. That kind of input is needed now more than ever as new "big science" initiatives and traditional "little science" projects chase hard-to-find federal research dollars, according to speakers at the American Association for the Advancement of Science's Thirteenth Annual Colloquium on R&D Policy held late last month in Washington, D.C.

President Reagan's fiscal 1989 budget request (C&EN, Feb. 29, page 7) seeks an average 14.5% increase over fiscal 1988 for nondefense R&D programs, though only a 2.2% increase for defense R&D. And as Rep. Doug Walgren (D.-Pa.), chairman of the House Subcommittee on Science, Research & Technology, pointed out, "The R&D budget as proposed would commit the government to a number of new, expensive, highly visible science projects." These include the space station, the Superconducting Super Collider (SSC), the national space plane, a project to map the human genome, and a 19% increase in the National Science Foundation's budget.

Walgren: competing priorities

C&EN staff photos

"Frankly," Walgren said, "I don't know where we will find the money to carry these programs through to completion. Simply putting them in the budget without setting priorities . . . is a questionable victory."

As he sees it, "big science" projects need to meet a very high burden of proof on what a particular project will deliver to society in terms of economic benefits or contributions to the national defense. He explained that one has to approach such projects with a great deal of caution because of their impact on science and technology funding as a whole.

He pointed out that funding the SSC would not only diminish ongoing programs in the Department of Energy's high-energy physics program, but programs in many other areas of science as well. For example, to reserve millions of dollars for the SSC, the Administration's 1989 budget cuts funding for R&D on fossil fuels in half.

Walgren believes that "the individual investigator is the pillar on which scientific advances rest, and there is no quicker way to chill scientific advances than not to have money to fund new researchers." Yet, as he also pointed out, the benefits of undirected basic research are hard to quantify. The question, he said, "is where does basic research fit into the equation of competing priorities?" Walgren warned attendees at the colloquium not to look to Congress for a great deal of wisdom in setting research priorities and urged individual scientists and scientific groups to get involved in the priority-setting process.

Bloch: hard choices must be made

Robert M. Rosenzweig, president of the Association of American Universities, touched on the same themes at the colloquium. He said that he "sees no realistic set of circumstances in which science will receive from the federal government all that it wants, needs, or deserves." This is true even though, as he pointed out, "in almost every respect the case for doing more is overwhelming. The opportunities for new knowledge have never been greater, nor has the need. And the people to supply it are in place and ready to go."

- **Vital for chemists, scientists, managers, and executives**
- **Meet the challenges of environmental concerns**
- **Learn to deal with federal regulations**

Toxicology for Chemists

Wednesday–Friday, June 1–3, 1988
Belleview Biltmore Resort & Spa
Belleair–Clearwater, Florida
A Short Course produced by the
American Chemical Society

Concern with toxic substances, so widespread now that it pervades almost all scientific activities, has created a large demand for toxicologists. Specialists who can handle problems in the production and distribution of chemicals, in the environment, and in foods, drugs, cosmetics, and wastes, and especially those who can effectively cope with the challenges of federal regulations will benefit from the intensive training and education this course provides. Learn the general principles of toxicology and how to apply a practical approach to making decisions in the field. Ideal for those who seek expertise in toxicology to advance or alter their careers.

Course contents cover:

Regulatory Affairs
Quantitation in Toxicology
Carcinogenesis
Acute and Chronic Toxicity Testing
Inhalation Toxicology
Mutagenesis
Teratogenic and Reproductive Effects
Toxicology of Skin and Eye
Neurotoxicology
Metabolism and Toxicokinetics
Predictive Toxicology/Risk Assessment

Course Instructors
Dr. Frederick J. DiCarlo, Consultant, U.S. Environmental Protection Agency, heads the faculty who teach this course. The lecturers are leaders in their fields, recognized nationally for their expertise and teaching experience.

For detailed information on this course, write, send coupon, or CALL COLLECT (202) 872-4508.

American Chemical Society
Education Division
1155 Sixteenth St., N.W.
Washington, DC 20036

☐ Please send me full details on the ACS Short Course "Toxicology for Chemists," to be held June 1–3, 1988 in Belleair–Clearwater, Florida.

Name ____________
Title ____________
Organization ____________
Address ____________
____
City, State, Zip ____________
Business Phone ____________

But, according to Rosenzweig, the reality for science is "that there is more to do than the country is willing, some would say able, to pay for right now. Someone will need to make the painful decisions." There is no question, he said, that the decisions will be political and will be made through political processes. The question is whether those decisions will be made well or badly. The difference between good and bad decisions frequently turns on the balance between narrow constituency interest and a conception of some broader set of interests.

It's that latter conception that Rosenzweig feels is lacking in the scientific community. He believes that neither scientists themselves nor those responsible for the institutions in which most science is conducted are "now prepared to participate constructively" in a priority-setting process. He pointed out "that there is no lack of passionate advocacy for every item on the agenda; there is a virtually total absence of help for any serious-minded government official who wants to think about how to think about the decisions that must be made."

He suggested that in their various forums scientists discuss, "as appropriate to each group, such questions as ... where the logic of science itself leads most compellingly; how to evaluate return on investment in the fullest meaningful terms; [if] the capacity of the system, its structures, and its people ... [can] sustain the level of effort that the current agenda calls for; and what decision-making processes are likely to produce the best investment choices."

Rosenzweig noted that "choices that are made without regard for the opportunities that will be foregone are not serious choices. We are drifting in the direction of just such easy, unserious thinking in our own counsels, thereby encouraging uninformed and dangerous decisions by government. We need to do better."

Just how painful the priority-setting process can be in the face of Congressional choices is exemplified by the recent experiences of

Direct federal support for chemical research is up 6% . . .

$ Millions	1989[a]	1988[b]	1987[c]	% change 1988–89
NSF	$160.0	$148.8	$147.2	8%
Energy[d]	138.0	131.1	116.5	5
Defense	38.3	34.7	40.4	10
NBS	12.2	10.1	9.7	21
TOTAL	**$348.5**	**$324.7**	**$313.8**	**7%**

. . . programs that support some chemistry are up 6% . . .

$ Millions	1989[a]	1988[b]	1987[c]	% change 1988–89
NIH[e]	$575.3	$533.1	$498.1	8%
EPA	259.8	244.9	247.0	6
Energy	82.8	99.8	101.7	−17
NSF	82.8	72.6	73.5	14
NBS	71.0	61.1	53.9	16
TOTAL	**$1071.7**	**$1011.5**	**$974.2**	**6%**

. . . and support for chemical engineering is up 36%

$ Millions	1989[a]	1988[b]	1987[c]	% change 1988–89
Energy	$1078.0	$775.2	$646.3	39%
EPA	59.5	53.2	52.2	12
NSF	37.1	33.4	33.0	11
TOTAL	**$1174.6**	**$861.8**	**$731.5**	**36%**

a Administration's request. b Estimate. c Actual. d Support for extramural "6.1" basic research. e Excludes funding for biochemical research. **Sources:** American Chemical Society, American Institute of Chemical Engineers

NSF Director Erich Bloch. As he told attendees, NSF started the 1988 budget cycle with high hopes. The Administration had proposed a 20% increase for NSF—the first installment in a plan to double the foundation's budget over five years. But it ended up very disappointed. Congress, which had been very supportive of the budget-doubling idea, ended up providing only a 3% increase for NSF's research activities and left it for the fourth year in a row with an essentially flat budget.

Still, Bloch said, even within those budget constraints every research division got an increase. For example, materials research got a 2% increase. But, he pointed out, "Mortgages carried forward from 1987 came home to roost." NSF could have funded all of the two- or more-year materials research grants. However, absolutely no new researchers could have been supported. Thus, NSF made the decision to cut back on existing materials research grants by 6 to 12% to support new research. "We're not proud of that, but it was the best we could do in a bad situation," Bloch explained.

The tight budget forced NSF to make a number of other tough decisions. The growth in undergraduate research support was slowed. Funding for current facilities, such as the supercomputer centers, was stretched out and no new ones are being funded. There was no increase in either grant size or numbers. And funding for the new science and technology centers program was deferred, because, as Bloch explained, there was "just no room in the budget to even make a start" on the program.

"The lesson of 1988," Bloch said, "is priorities." And he warned that many more such hard choices must be made even if NSF's fiscal 1989 request for a 19% budget increase is successful. He doesn't think it will be. Even though there are "good" budget resolutions in both the House and Senate (C&EN, April 25, page 5), Bloch noted that neither would support all of the increases in research funding that the Administration requested. Noting that "Congress knows that there are other needs than science," Bloch predicted that "the best we can expect is one half to three quarters" of what was requested.

Noting that NSF had made specific choices within its own budget, even though it would have been easier to make across-the-board budget cuts because "then nobody could have complained," Bloch urged the scientific community to do the same thing. He admitted that it would be difficult for the highly pluralistic scientific community to speak with one voice, but suggested that the national academies or NSF advisory committees might serve as forums to debate the issues and build a consensus on priorities. However, he warned that if the scientific community doesn't learn to speak coherently, it won't be effective in getting all or even most of the support it believes it needs. □

28 086
14 Si
Petrarch —
The
Organosilicon
Experts

New Register and Review provides data on over 1000 products

Synthetic Reagents
Blocking Agents
Surface Modification
Coupling Agents
Silicone Fluids
Custom Syntheses

PETRARCH SYSTEMS SILANES

hüls
HÜLS AMERICA INC.
CHEMICAL DIVISION

2570 Pearl Buck Road, Bristol, PA 19007
(215) 781-9255

In Europe: ABCR Gmbh & Co.
Schoemperlenstr. 5 D-7500 Karlsruhe-21
West Germany (0) 721-563088

DN-11-SIJ

CIRCLE 13 ON READER SERVICE CARD

June 2–3, 1988
University of Toronto, Ontario, Canada

FIRST INTERNATIONAL SYMPOSIUM ON POLYMER ANALYSIS AND CHARACTERIZATION

This two-day symposium will consist of poster sessions, lectures, and roundtable discussions on recent advances in chromatography, spectroscopy, light scattering, rheology, thermal analysis, and solution properties of synthetic and naturally occurring polymers.

Lecturers include: S. T. Balke, G. C. Berry, H. N. Cheng, S. Z. D. Cheng, J. V. Dawkins, G. Glöckner, N. Hadjichristidis, A. E. Hamielec, W. S. Hancock, J. Janča, J. L. Koenig, P. Kratochvil, W. J. MacKnight, S. Mori, P. Munk, G. D. J. Phillies, M. Rinaudo, R. S. Stein, and P. Vouros.

Registration fee: $325 (US $). To register, please send form and fee, payable to ISPAC, Ltd., to: **Dr. Howard G. Barth, 207 Welwyn Rd., Wilmington, DE 19803.**

For further information, please write or call Dr. Barth at (302) 695-4354.

Name____________________
Company____________________
Address____________________
____
Telephone____________________

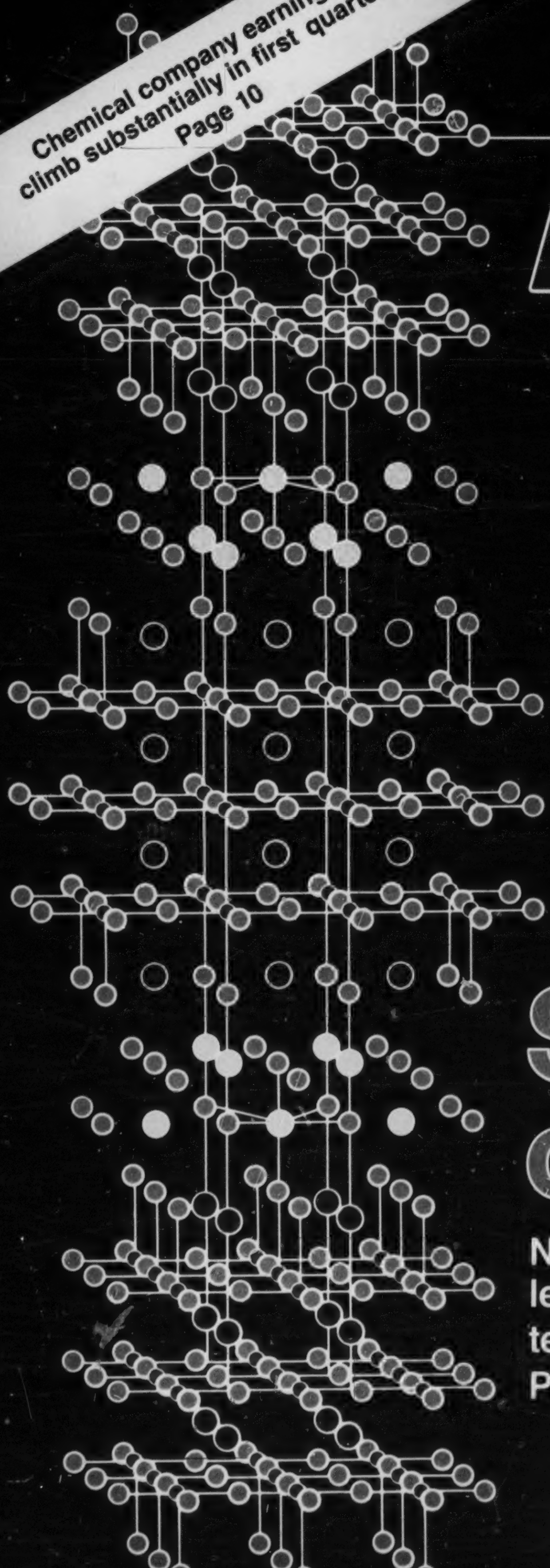
CIRCLE 33 ON READER SERVICE CARD

A1250-1
5/18/88

MAY 16, 1988

CHEMICAL & ENGINEERING NEWS

Chemical company earnings
climb substantially in first quarter
Page 10



Super-conductors

New structures
lead to higher
temperatures
Page 24

0511179C098 9 K AR6620SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

②

Volume 66, Number 20
CENEAR 66 (20) 1–56
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

MAY 16, 1988

News of the Week

- **May 5 explosion and fire at a Shell Oil refinery in Norco, La., eliminated 6% of U.S. ethylene capacity, further tightening supplies of this key chemical.** **Page 4**
- **Recent destruction of one of only two U.S. plants that produce ammonium perchlorate oxidizer may cause supply shortages that could delay space shuttle and military missile programs.** **Page 5**
- **Carbide-funded investigation by Arthur D. Little Inc. into the cause of the 1984 chemical disaster in Bhopal, India, supports Carbide's employee sabotage theory.** **Page 6**
- **Dow Chemical is deeper into Italian chemical deals with its purchase of 5% stake in Montedison and involvement in a Montedison restructuring plan.** **Page 6**

Letters 2

Concentrates

Business 7
Government 16
Science/Technology 23

The Departments

ACS Comment 33
Awards 37
Newscripts 56

Business

Earnings of major U.S. chemical companies soared 66% in the first quarter on sales rise of 20%. **Page 10**

Production of aerosol units increased 3.6% in 1987, marking the fifth consecutive year of growth for the industry. **Page 15**

Government

Bill banning polymer-based weapons not detectable by airport security systems was passed by the House last week in response to concerns about possible terrorist use of plastic guns. **Page 17**

Study contending that nitrates in acid rain adversely affect marine life raises environmental concerns in government and industry. **Page 19**

An international research program in genetics and neuroscience is being established by the Japanese. **Page 21**

Science

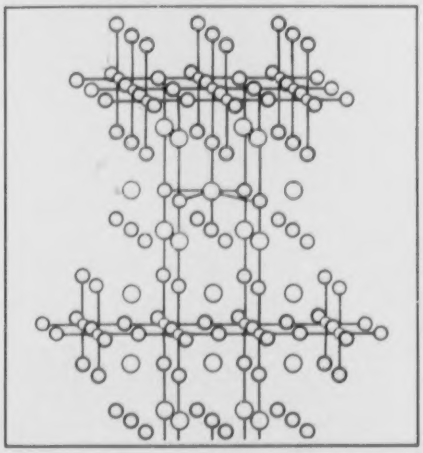
Berkeley chemist Peter G. Schultz wins NSF's prestigious Alan T. Waterman Award. **Page 29**

Education

NSF's directorate for science and engineering education is back at work supporting a number of important educational programs after having been eliminated in 1982 by Reagan Administration budget cuts. **Page 31**

ACS News

ACS Board approves 133 new or continuing Petroleum Research Fund grants totaling \$3.6 million. **Page 34**



Cover: Structure of 125 K superconductor $Tl_2Ca_2Ba_2Cu_3O_{10}$, as determined by Du Pont researchers. Thallium atoms are yellow, calcium purple, barium green, copper red, and oxygen blue

Cover Story

New superconducting materials that work at temperatures up to 125 K contain thallium or bismuth but no rare-earth elements. **Page 24**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. C Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

Fascinating superconductivity

SIR: I have never pretended any expertise in the field of superconductivity, but the continuing reports (C&EN, Sept. 21, 1987, page 33; Feb. 15, page 4; and March 14, page 4) keep fascinating, and I cannot resist offering my two cents worth.

I have been intrigued to discover that in all the yttrium, bismuth, and thallium compositions detailed, thus far, the copper atoms of oxidation state +2 have the expected partial positive charge, but those in oxidation state +3 bear partial negative charge. This seems somewhat unusual, but whether or not it bears any relationship to superconductivity remains to be determined. Since as yet no one really seems to know how superconductivity originates in these and similar compositions, this new information may provide a useful clue to other compositions that would also satisfy this criterion, and might or might not possess the desired property of superconductivity. There are many possibilities, not necessarily restricted to those containing copper.

R. T. Sanderson
Fort Collins, Colo.

The alternative doctorate

SIR: Slightly over a year ago C&EN published a letter of mine (March 16, 1987, page 33) that suggested the American Chemical Society institute an alternative doctorate to be granted to deserving researchers who meet certain reasonably stringent criteria. Kurt J. Rorig (C&EN, May 25, 1987, page 2) endorsed my proposal in concept, stating, "In my chemical career I have worked with a score of researchers who richly deserved, but did not have, the honor and prestige of a Ph.D." He pointed out, however, that the granting of doctorate degrees has historically been the province of universities and suggested that a Diplomate in Chemical Research (Dipl. C.R.) might be more appropriate.

Mario R. Altimura (C&EN, Nov. 23, 1987, page 2) also endorsed the need for some recognition for deserving non-Ph.D. researchers whom he characterized as "the unsung heroes of chemistry." Altimura recognized the importance of the term "doctor" and pointed out the distinction between a degree and a title. He suggested that ACS could quite properly grant a title such as Doctorate in Chemical Research (D.C.R.) to deserving individuals. In my original letter, I suggested D.Sc. in Chemistry or Doctor of Chemistry as alternatives to Ph.D., but I am equally comfortable with Altimura's suggestion.

A parallel indication of the need for some sort of recognition of successful non-Ph.D. researchers has been provided by the letters protesting J. R. Mohrig's comments (C&EN, Sept. 28, 1987, page 24) regarding the "amateur" status of "maverick" B.S. and M.S. chemists. A. A. Jeknavorian (C&EN, Dec. 7, 1987, page 46), for example, referred to "the unquestionable contribution that non-Ph.D. chemists have made to the field of chemistry." It is clear that many chemists recognize the contributions of their non-Ph.D. colleagues. It is also clear that, unless a device is established for granting a doctorate to those whose performance has demonstrated that they fully deserve one, these individuals will continue to be viewed by many as second-class chemists—if not amateurs or mavericks.

This brings me to the recent letter by Robert M. Kuhn (C&EN, March 7, page 4). Kuhn states: "The doctorate carries with it the implication that the recipient not only can do original research but is willing to sacrifice nearly everything for it: six to eight years of practically uncompensated labor . . . and a near total lack of family life." He concludes: "For a similar contribution anyone can have the real thing." Kuhn makes a doctorate sound like an endurance prize available to anyone willing to work hard and make unreasonable sacrifices.

Although success in chemistry—as in any worthwhile endeavor—does require hard work and some sacrifices, these should not be ritualized into a form of hazing that would-be initiates must endure to gain acceptance. Chemistry is a profession and not a fraternity. Nevertheless, Kuhn has identified the principal reason why many good researchers have elected to bypass a traditional doctorate. Many intelligent, hard-working chemistry graduates simply are unwilling to submit to "six to eight years of practically uncompensated labor" and "a near total lack of family life." They are willing to work hard, and capable of doing so productively, but they wish to have a family life and must earn a living wage. When such chemists have demonstrated through their work a competence equal to that we expect of holders of a doctorate, they should be able to attain the recognition, prestige, and compensation that a doctorate confers. They should not be punished for having attained and demonstrated their competence via an alternative route.

David R. Schryer
Hampton, Va.

Chemical Earnings Continue Big Gains in First Quarter

Composite profits of 30 major U.S. chemical firms climbed 66% on sales up 20%; income of oil, diversified producers also rose, but less markedly

Marc S. Reisch, C&EN New York

Chemical industry sales and earnings continued to climb in the first quarter of 1988, building on the momentum achieved last year. According to composite results of a representative group of the largest U.S. chemical companies, profits rose a heady 66% over the same period in 1987. Earnings also increased at diversified companies that are producers of chemicals, but not quite so dramatically.

Earnings of oil companies charted by C&EN also rose in the first quarter as prices for oil and their refined fractions were higher than the year-earlier quarter. And because of the good climate for chemical sales, earnings for the chemical operations of oil companies increased significantly over the same period last year.

Chemical operations excel at oil companies

	First-quarter earnings on chemical operations[a]		
$ Millions	1988	1987	% change
Amoco	$169	$ 88	92%
Chevron	109	52	110
Exxon	308	186	66
Mobil	134	43	212
Shell	143	40	258
Texaco	47	8	488
TOTAL	$910	$417	118%

a After-tax earnings.

Sales and earnings of the chemical industry continue to grow at a phenomenal pace, setting the stage for another record year for the industry. Last October, observers thought that the industry might suffer following the stock market crash. Market uncertainty at the time led observers to believe that the outlook for 1988 might not be very good.

However, record fourth-quarter sales followed by almost equally strong first-quarter sales have shown that the sales and earnings momentum behind the chemical industry still has a lot of steam. Demand for commodity petrochemicals in particular is strong, straining capacity and forcing price increases.

The industry has increased its first-quarter output 9% from the year-earlier quarter, mostly via debottlenecking, rarely through the addition of new plant capacity. With the memory of plant shutdowns in the late 1970s and early 1980s still fresh, industry executives are reluctant to repeat the mistake of overbuilding capacity.

With capacity tight in most major chemical arenas, the Commerce Department reported that prices in the chemical and allied industries were 7.4% higher in the first quarter than the same period in 1987. And inasmuch as energy and feedstock prices remained fairly stable throughout the quarter, profit margins have risen considerably for most of the chemical industry. For the 30 largest chemical companies tracked by C&EN, after-tax earnings as a percentage of sales increased to 8.9%

Chemical industry leaders for the first quarter

Sales				Earnings[a]			Profitability		
Rank 1988		$ Millions	Rank 1987		$ Millions	Rank 1987		Earnings as % of sales	Rank 1987
1	Dow Chemical	$3981.0	1	Dow Chemical	$507.0	1	Arco Chemical	18.5%	2
2	Monsanto	2127.0	2	Monsanto	210.0	2	Georgia Gulf	17.4	14
3	Union Carbide	1947.0	3	Arco Chemical	108.0	5	International Flavors	16.0	1
4	W. R. Grace	1297.0	5	Union Carbide	101.0	3	Vista Chemical	15.4	11
5	American Cyanamid	1148.5	4	Quantum Chemical	100.5	10	Dow Chemical	12.7	8
6	Quantum Chemical	832.9	7	American Cyanamid	79.2	4	Quantum Chemical	12.1	22
7	Hercules	661.6	6	Rohm & Haas	62.2	6	Ethyl	11.1	3
8	Rohm & Haas	620.5	8	Air Products	55.7	9	Nalco Chemical	10.6	7
9	Air Products	618.9	9	Ethyl	53.1	8	Betz Laboratories	10.6	4
10	B. F. Goodrich	588.0	11	Hercules	39.8	7	Rohm & Haas	10.0	5

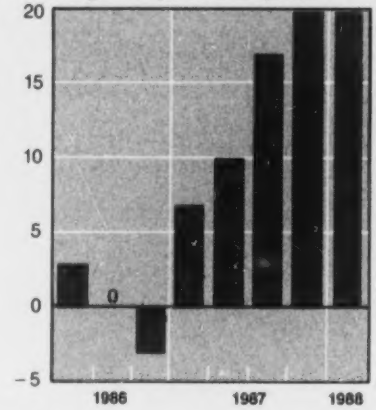
Note: For 30 chemical companies listed on page 12. a After taxes.

Chemical industry 1988 first-quarter results

- **Sales climbed 20%**
- **Earnings jumped 66%**
- **Profit margins neared 9%**
- **Production rose 9%**
- **Prices increased 7.4%**

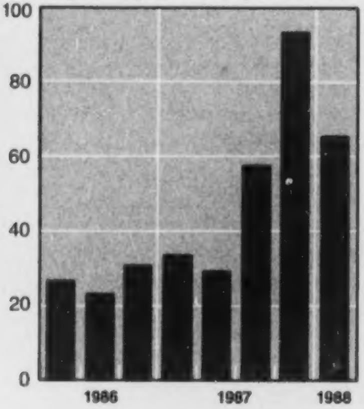
Sales

% change from year-earlier quarter



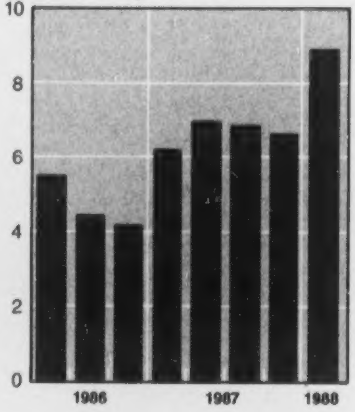
Earnings

% change from year-earlier quarter



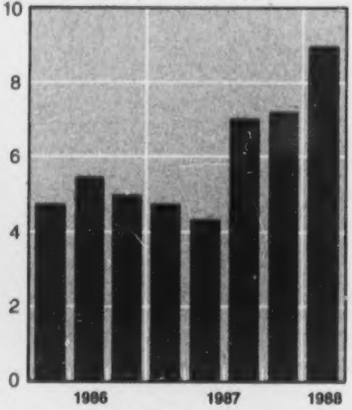
Profit margins

After-tax earnings as % of sales



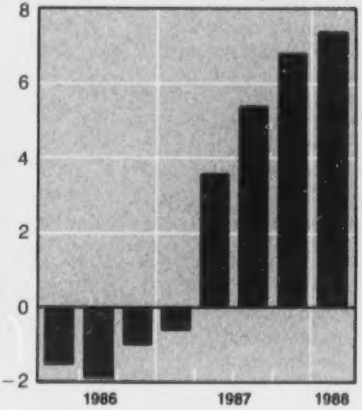
Production

% change from year-earlier quarter



Prices

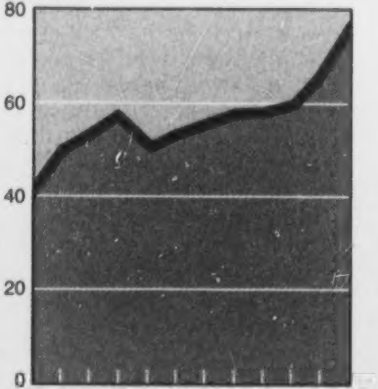
% change from year-earlier quarter



Sales in 1988 will increase about 15% and earnings will climb 35%, hiking profit margins to 7.9%

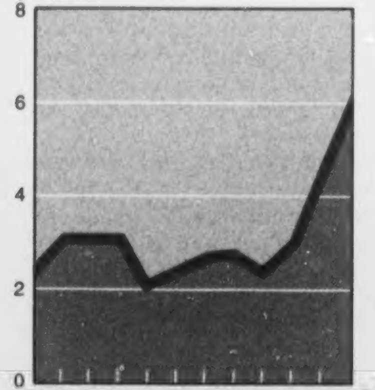
Annual sales

$ Billions



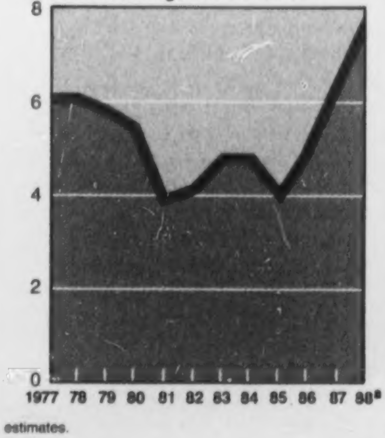
Annual earnings

$ Billions



Annual profit margins

After-tax earnings as % of sales



Note: All sales, earnings, and profit-margin data are based on combined results of 30 companies listed on page 12. a C&EN estimates.

Earnings and profit margins increased dramatically in first quarter

	FIRST-QUARTER 1988						12-MONTH RUNNING DATA			
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Change from 1987		Profit margin	
	($ millions)		Sales	Earnings	1988	1987	Sales	Earnings	1988	1987
Air Products[c]	$ 618.9	$ 55.7	17%	36%	9.0%	7.8%	11%	31%	8.4%	7.1%
American Cyanamid[c]	1,148.5	79.2	13	29	6.9	6.1	10	23	6.3	5.6
Arco Chemical[c]	583.0	108.0	30	83	18.5	13.1	30	79	14.7	10.6
Aristech	260.3	22.7	25	67	8.7	6.5	27	58	8.1	6.5
Betz Laboratories	105.8	11.2	19	15	10.6	11.0	−6	−22	4.2	5.1
Cabot[c]	465.9	18.4	23	−5	3.9	5.1	1	17	5.2	4.5
Chemed	99.7	4.5	9	6	4.6	4.7	5	44	5.3	3.8
Crompton & Knowles	63.6	3.6	14	51	5.6	4.2	24	85	10.5	7.0
Dow Chemical[c]	3,981.0	507.0	32	106	12.7	8.2	14	9	11.0	11.6
Ethyl[c]	480.1	53.1	23	14	11.1	11.9	25	359	6.3	1.7
First Mississippi	62.3	1.2	−13	−47	2.0	3.3	21	36	4.1	3.6
H. B. Fuller	154.6	4.7	13	30	3.1	2.7	−2	189	5.0	1.7
Georgia Gulf	221.9	38.6	44	268	17.4	6.8	108	336	14.8	7.1
B. F. Goodrich[c]	588.0	25.0	21	558	4.3	0.8	15	18	10.4	10.2
W. R. Grace[c]	1,297.0	38.7	35	231	3.0	1.2	28	52	12.1	10.2
Hercules[c]	661.6	39.8	−1	−17	6.0	7.1	27	def	3.5	def
International Flavors	224.0	35.9	25	30	16.0	15.4	2	−4	7.4	7.9
International Minerals	322.8	32.0	−29	72	9.9	4.1	21	27	14.6	14.0
Loctite	108.9	10.5	21	21	9.6	9.7	4	def	5.3	def
Lubrizol	293.2	19.0	8	−14	6.5	8.1	28	32	9.6	9.3
Monsanto[c]	2,127.0	210.0	14	52	9.9	7.4	6	−11	6.2	7.4
Nalco Chemical	236.0	25.0	20	38	10.6	9.2	13	58	6.4	4.6
Olin[c]	567.0	29.0	14	19	5.1	4.9	16	44	9.8	8.1
Pennwalt	328.4	13.7	24	7	4.2	4.9	17	60	4.1	3.0
Petrolite	79.5	4.7	24	16	5.9	6.3	11	7	4.4	4.5
Quantum Chemical[c]	832.9	100.5	27	248	12.1	4.4	10	3	5.5	5.8
Rohm & Haas[c]	620.5	62.2	16	17	10.0	10.0	21	169	7.8	3.5
Union Carbide[c]	1,947.0	101.0	16	53	5.2	3.9	11	7	8.7	9.1
Vista Chemical	215.6	33.3	42	196	15.4	7.4	12	69	3.7	2.5
Witco[c]	393.9	20.0	18	51	5.1	4.0	11	14	4.9	4.8
Total 15 larger firms	**$16,241.1**	**$1459.5**	**20%**	**69%**	**9.0%**	**6.4%**	**15%**	**61%**	**7.3%**	**5.2%**
Smaller 15 firms	**$ 2,847.7**	**$ 248.5**	**21%**	**51%**	**8.7%**	**7.0%**	**18%**	**67%**	**8.1%**	**5.7%**
GRAND TOTAL	**$19,088.8**	**$1708.0**	**20%**	**66%**	**8.9%**	**6.5%**	**16%**	**62%**	**7.4%**	**5.3%**

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c One of the 15 largest companies. **def** = deficit.

in the first quarter, up from 6.5% in the year-earlier quarter.

Demand for chemicals has increased not only within the U.S. but globally. Most companies cited strong earnings in foreign countries as well as increases due to the effect of currency translations because of the weak U.S. dollar as a factor in their first-quarter profitability. In addition, the Commerce Department continues to cite figures that show a trade balance continuing to grow in favor of the U.S.

Domestically, however, there are still some weak spots. According to Commerce, new housing permits continue to decline as they did throughout last year. Interest rates have begun to inch up, a move that does not favor a near-term improvement in the housing industry, and may presage a slowdown later in the year.

Commerce figures also indicate that auto output continues to decline and that dealer inventories remain high. As a result chemical sales to auto makers may continue to dampen. One bright note, however, are plans by Chrysler, Ford, and Japanese auto makers with U.S. production facilities to export autos made in the U.S. to foreign markets.

Agricultural chemical markets remain weak. Though they are down from 1987 levels, fertilizer materials continue to be in oversupply.

Despite these few drawbacks, the 30 chemical companies charted by C&EN registered composite earnings in the first quarter of $1.71 billion, up 66% from first-quarter 1987 on a sales boost of 20% to $19.1 billion.

On a quarter-to-quarter basis, combined earnings for the 30 companies climbed 50% in the first quarter from a strong fourth quarter in 1987. Composite sales were up 13% from the fourth quarter of last year. The first-quarter profit margin average of 8.9% was the highest recorded in the past two years.

Sales of the 15 larger chemical

Sales, earnings up for most oil and diversified companies

	FIRST-QUARTER 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987
OIL AND GAS COMPANIES						
American Petrofina	$ 604.7	$ 30.4	12%	53%	5.0%	3.7%
Amoco	5,761.0	469.0	10	80	8.1	5.0
Ashland[c]	1,945.8	20.6	20	2790	1.1	0
Chevron	7,500.0	442.0	10	68	5.9	3.9
Exxon	22,008.0	1,455.0	13	36	6.6	5.5
Kerr-McGee	663.8	10.3	21	−49	1.5	3.7
Mobil	13,800.0	505.0	18	107	3.7	2.1
Occidental Petroleum	4,476.0	111.0	8	52	2.5	1.8
Phillips Petroleum	2,900.0	103.0	14	def	3.6	def
Shell Oil	5,051.0	345.0	12	219	6.8	2.4
Sun Co.	2,390.0	60.0	6	58	2.5	1.7
Texaco	3,330.0	242.0	18	105	7.3	4.2
DIVERSIFIED MANUFACTURERS						
Allied-Signal	2,942.0	112.0	12	10	3.8	3.9
Borden	1,602.3	52.4	12	19	3.3	3.1
Du Pont	7,992.0	590.0	12	51	7.4	5.5
Eastman Kodak	3,328.3	260.1	25	46	7.8	6.7
Engelhard	511.4	13.4	−5	−1	2.6	2.5
FMC	713.9	24.2	−1	−4	3.4	3.5
Ferro	241.2	11.2	18	65	4.6	3.3
GAF	216.5	21.8	13	6	10.1	10.8
Koppers	306.7	−4.4	13	def	def	def
3M	2,602.0	277.0	18	30	10.6	9.7
Morton Thiokol	604.4	41.5	16	14	6.9	7.0
PPG Industries	1,373.0	118.6	9	36	8.6	6.9
Tyler	292.9	1.7	14	69	0.6	0.4
Vulcan Materials	202.7	15.6	20	48	7.7	6.2

a After-tax earnings from operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c Includes some nonrecurring or extraordinary items. **def** = deficit.

companies grew 20%, compared with 21% for the smaller 15 companies, from the year-earlier quarter. The larger, more diversified firms continued to outperform the smaller companies in profitability. For the 15 larger firms, composite earnings climbed 69% to total $1.46 billion on sales of $16.2 billion. Profit margins for the first quarter for the 15 firms averaged 9% compared with 6.4% in the first quarter of 1987.

For the 15 smaller companies, first-quarter earnings increased a composite 51% from last year's first quarter to $249 million on sales of $2.85 billion. Profit margins at the smaller companies averaged 8.7% in the first quarter of this year compared with 7.0% in the same quarter in 1987.

Higher operating rates and strong worldwide demand accounted for the strong performance by Du Pont, the largest U.S. chemical producer. According to chairman Richard E. Heckert, "The solid gain in first quarter performance reflects continued strong worldwide demand and further progress in reducing costs and improving overall efficiency." He says that the improvements in first-quarter earnings were led by the industrial chemicals and polymer products segment. In addition, an improvement in global demand for agricultural chemicals helped lift that segment out of the doldrums.

For Dow Chemical, whose earnings were up a whopping 106%, president and chief executive officer Frank P. Popoff says that "increases in both prices and volume contributed to the first-quarter results." He notes that basic chemicals and plastics, which continue to be the foundation of Dow's business, had a record-setting quarter. "Costs remain stable, volume has increased, and there is no weakness apparent in either the product lines or geographical areas," Popoff says. "We are experiencing strong demand globally in these basic products, and, although the growth rates may moderate in 1989, we anticipate continued growth into the 1990s," he adds.

Strong demand also contributed to Monsanto's excellent results in the first quarter. The company registered a 52% increase in its profits from last year's first quarter. Richard J. Mahoney, Monsanto chairman and chief executive officer, says, "Chemicals had excellent sales and operating income from strong demand for its major products and very high capacity utilization."

The Monsanto chief executive also noted the contribution of strong overseas sales to the corporation's bottom line. "Sales and operating income outside the U.S., both from exports and non-U.S. production, substantially exceeded levels in 1987." He adds that "higher margins on key products are expected to continue this year because of strong worldwide demand and some announced price increases."

The strength of the international market was evident again in remarks by Allen F. Jacobson, chairman and chief executive officer of 3M. "Earnings benefited from double-digit worldwide unit growth, increased productivity, weakening of the U.S. dollar, and a lower effective tax rate." Jacobson says that the strength of the company's business overseas was not due only to favorable currency exchange rates. He points out that the company's unit volume sales outside the U.S. grew about 15% and that international sales exceeded $1 billion for the first time in any quarter. "Our efforts to increase penetration of international markets continue to show positive results," he adds.

Strong global markets helped PPG Industries weather a weak U.S. housing and auto market. "One result of our strategic emphasis on globalization," says board chairman Vincent A. Sarni, "is that lower North American auto production and housing starts did not impede PPG's ability to achieve substantial growth." Sarni attributes PPG's 36% earnings growth in the first quarter to "strong chemical and glass fiber results, as well as substantial performance gains by European operations coupled with favorable currency translations."

Koppers, which recorded a 13% sales increase in the quarter compared with the year-earlier period, had an overall earnings decline of 4.4%. The company would have shown a profit, however, if it were not for exceptional charges against earnings. "We had an abnormal increase of nearly $7 million in our corporate overhead as the result of expenses that were external to our first-quarter performance," says company chairman Charles R. Pullin. "Most significant were expenses related to the hostile tender offer led by Beazer . . . and Shearson Lehman Hutton." However, Koppers' operating income in chemicals and allied products rose more than 34%, and losses in construction materials and service were limited compared with the year earlier, he says. □

Pharmaceutical earnings rose markedly in first quarter

Combined first-quarter earnings of 13 pharmaceutical companies tracked by C&EN amounted to $1.82 billion, a 14% rise over the year-earlier quarter.

Combined sales for the companies totaled $13.2 billion, up 15%. Collectively, the companies recorded a profit margin (after-tax earnings as a percentage of sales) of 14%, the same as in first-quarter 1987. This group has consistently reported profit margins in excess of either the chemical, diversified, or oil and gas companies surveyed by C&EN.

Like these other groups, the pharmaceutical group benefited from the improvement of foreign business and the resultant overseas currency translation bonus attributed to the weaker U.S. dollar. Highly dependent on new product development to drive both sales and profitability, most pharmaceutical firms brought new products to market last year and this was reflected in the higher sales and earnings they registered for the quarter.

Merck, whose earnings rose 35% in the quarter on a 29% sales gain, had strong unit volume gains both in its domestic markets and international operations. According to chairman P. Roy Vagelos, "Sales outside the U.S. accounted for 51% of first-quarter sales, compared with 49% for the same period last year." He says that Merck's "income growth and improved earnings margins resulted from strong unit volume gains, a better product mix, the continuation of cost controls, and productivity improvements as well as the favorable effect of exchange."

SmithKline Beckman's chairman and chief executive officer Henry Wendt also notes the improvement in his company's sales and profit picture as a result of currency translations. The weaker U.S. dollar, he points out, had the effect of adding $55 million to corporate sales. SmithKline's after-tax earnings were $167 million in the first quarter, up 14% over the year-earlier period.

Pfizer attributes its strong 47% earnings rise to strong sales in all five of its business segments. Its pharmaceutical sales increased 16%, says company chairman Edmund T. Pratt Jr. Sales in other divisions were up as well. Specialty chemical sales of Pfizer increased 17%, material sciences sales 18%, agricultural sales 15%, and consumer sales 17%, he says.

Given the strong market and Pfizer's confidence in developing new products for its markets, Pratt adds that products developed via R&D "combined with strong sales in our current product lines have positioned Pfizer well to meet its long-term growth objective of at least 10 to 15% earnings growth per year."

Upjohn, too, noted the strength of foreign markets. Company chairman and chief executive officer Theodore Cooper says that foreign sales increased 18% and amounted to 40% of consolidated sales. The 11% sales increase for the first-quarter of 1988, he says, was due to a 6% increase in volume, a 1% increase in price, and a 4% increase from foreign currency fluctuations.

Schering-Plough's chairman and chief executive Robert P. Luciano says that higher sales and earnings in the first quarter were the result of continued gains by the company's worldwide pharmaceutical business and a solid performance by the company's U.S. consumer operations. Earnings of the company rose 20% on a 10% gain in sales. Luciano forecasts earnings increasing about 25% for 1988.

Like the chemical, diversified, and oil companies charted by C&EN, pharmaceutical companies are benefiting this year from lower corporate tax rates. Schering-Plough, for instance, forecasts its rate will be 2% below that of 1987.

	FIRST-QUARTER 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987
Abbott Labs	219.3	8.4	9	13	3.8	3.7
American Home Products	$1,412.6	$237.1	10%	10%	16.8%	16.8%
Baxter Travenol	1,635.0	91.0	12	38	5.6	4.5
Becton Dickinson	463.5	38.9	19	17	8.4	8.5
Bristol-Myers	1,520.0	210.6	13	−25	13.9	20.8
Eli Lilly	1,072.1	233.2	11	15	21.8	20.9
Merck	1,436.8	271.4	29	35	18.9	18.1
Pfizer	1,297.9	196.3	16	47	15.1	11.9
Schering-Plough	752.5	101.5	10	20	13.5	12.4
SmithKline Beckman	1,162.4	166.5	16	14	14.3	14.6
Squibb	596.9	90.9	27	31	15.2	14.8
Upjohn	662.4	95.4	11	18	14.4	13.5
Warner Lambert	927.8	83.5	14	14	9.0	9.0
TOTAL	$13,159.2	$1824.7	15%	14%	13.9%	13.9%

a After-tax earnings from operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales.

New acid rain study stirs interest, concern

Lois R. Ember, C&EN Washington

Among the slew of studies on acid rain, a recent one highlighting a not-so-new but often overlooked aspect of the problem—the nutrient effect of nitrate deposition on marine life—has been stirring vast interest, if not concern, in some quarters.

Members of Congress have cited it in their calls for acid rain control programs. A powerful member of the House of Representatives has asked the Environmental Protection Agency to review it. And some observers have even suggested that it has the potential for dislodging the logjams holding up action on acid rain control bills in both houses of Congress.

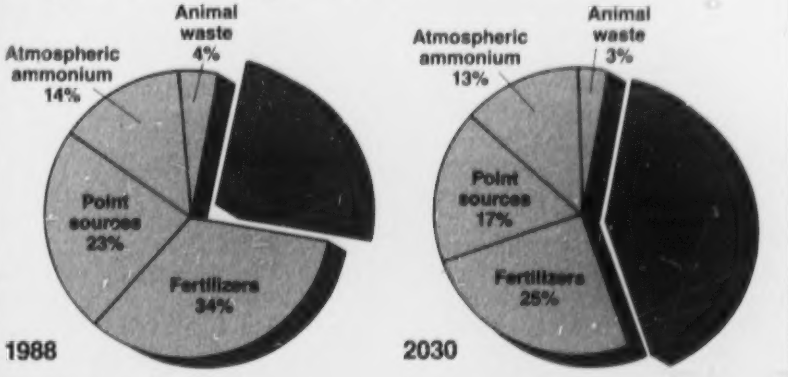
This is powerful stuff for a study that breaks little new ground scientifically. What the Environmental Defense Fund has done in its report, "Polluted Coastal Waters: The Role of Acid Rain," is to move the acid rain debate beyond the issues of damage to freshwater bodies and forests. By calculating the effect of acid deposition on estuaries along the eastern coast, particularly the Chesapeake Bay, EDF has focused the spotlight on acid rain's effect on marine ecosystems.

As one electric utility scientist explains, the EDF effort links atmospheric deposition with aquatic nutrient effects. "The idea that nitrate in acid rain might add to the nutrient loading of estuaries is not a new hypothesis. We just went ahead and did the calculations," EDF staff scientist Diane C. Fisher admits. Though not new, "the idea has been largely overlooked by managers at state and federal levels who are called upon to develop programs to manage estuaries," she says.

Using data collected by EPA's Chesapeake Bay Program, the National Atmospheric Deposition Program, and state agricultural agencies, EDF has concluded that the nitrate component of acid rain is significant enough to adversely affect the vitality of the Chesapeake Bay, which is a rich spawning ground for marine life. From calculations based on the data, EDF figures that fully 25% of the nitrogen loading of the bay comes from atmospheric deposition of nitrate in acid rain. As a source of nitrogen to the bay, acid rain is exceeded only by nitrogen from fertilizers.

EDF is not considering nitrate's contribution to the acidity of the bay, but rather its nutrient effect. That is, deposited nitrate encourages the vigorous growth of algae. Algae blooms choke life from the bay by using up its oxygen and screening out its sunlight. Therefore, the bay's ecosystem becomes unbalanced and marine life is adversely affected.

Atmospheric sources of nitrate to Chesapeake Bay likely to increase by year 2030



Source: Environmental Defense Fund

According to Steven P. Lindenberg, the Electric Power Research Institute's manager of technology transfer, "EDF's approach is reasonable and the methodology is not flawed, but the report does not consider all the aspects it should have." An industry source says a major flaw in EDF's analysis is that it does not include an evaluation of the bay's own contribution to its nitrogen loading. The bay's sediment is rich in nitrogen and phosphorus. When stirred, this sediment becomes a major source of nitrogen to bay waters.

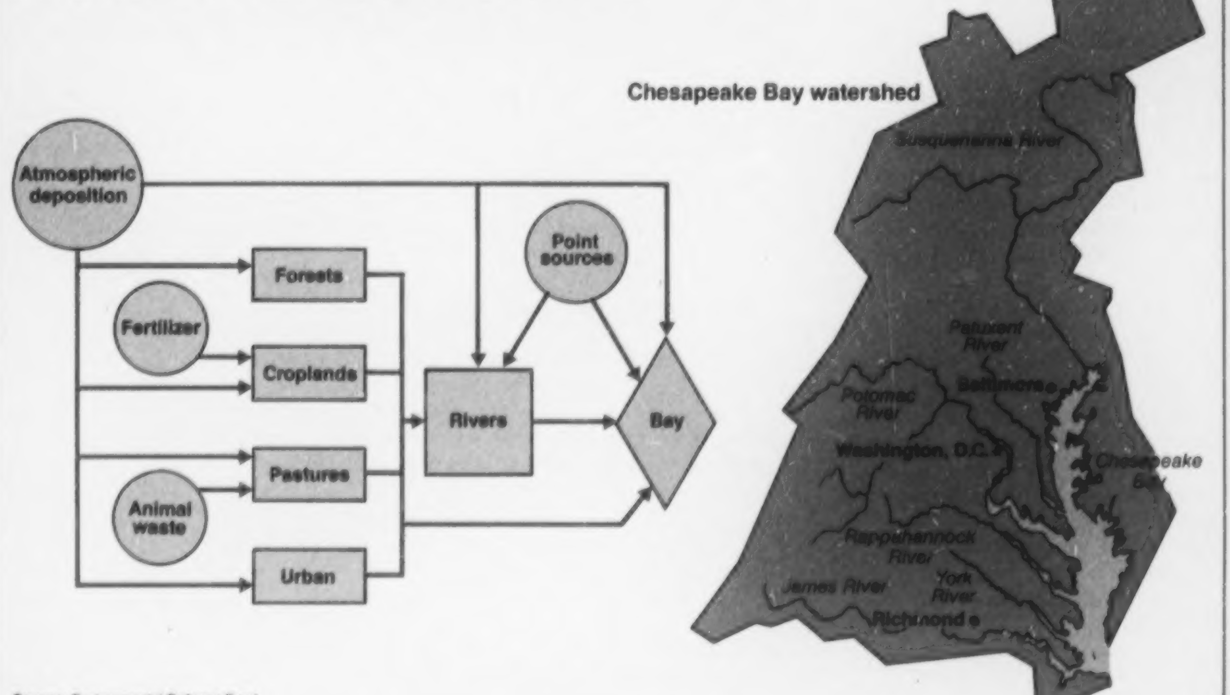
An EPA scientist who is reviewing EDF's study says, "It is not as rigorous as it should be." Further, he says, "EPA has a program in place—the Chesapeake Bay Program—to study the issue," which he feels probably would be worth looking at in more detail.

EPA's review of the EDF study was prompted by a request from Rep. John D. Dingell (D.-Mich.), the powerful chairman of the House Energy & Commerce Committee. Dingell, who represents the automotive center of Michigan, has long resisted passage of acid rain legislation.

Dingell is obviously concerned about the implications of the EDF study or he wouldn't have requested the review, a House committee staffer says. The reason for his concern is the source of nitrate in acid rain: nitrogen oxide emissions from the burning of fossil fuels in vehicles and electric power plants.

EPA will complete its review by the end of the month. It is likely to come down hard on the EDF study. Outside experts reviewing the study for EPA have mentioned several flaws in EDF's reasoning. One of the major ones, according to a knowledgeable source, is that EDF assumes that all of the nitrogen falling in the Chesapeake Bay watershed, which is largely terrestrial, enters the bay's waters. Nitrogen input to the watershed from acid rain is significant, but according to the reviewers, only a small fraction of this nitrogen actually reaches the bay.

Nitrogen flow in the Chesapeake Bay watershed



Source: Environmental Defense Fund

EDF scientist Fisher disputes this assessment. "We did take into account the nitrogen retention of the watershed," she says. The percentage contribution of atmospheric nitrogen to the nitrogen loading of the bay is 25% now and could increase to 42% by 2030 if federal nitrogen oxide standards are not tightened, she says. These percentages are calculated by using a watershed retention factor, Fisher explains. Further, she adds, "A significant amount of nitrogen reaches the bay from rainfall directly."

While the scientists battle over the science, politicians feel free to use EDF's conclusions. Speaking from the House floor, Rep. Marge Roukema (R.-N.J.) implored her colleagues on the Energy & Commerce Committee to "pass a Clean Air Act overhaul this year to eradicate the environmental scourge that is acid rain." Why now? Because, she said, "Recent reliable statistics point for the first time to evidence that acid rain is now a major threat to marine life in Atlantic coastal waters."

In his recent address to Congress, Canadian Prime Minister Brian Mulroney said: "The one thing acid rain does not do is discriminate. It is despoiling your environment as inexorably as it is ours. It is damaging your environment from Michigan to Maine, and threatens marine life on the eastern seaboard."

Ross Glascow, first secretary at the Canadian Embassy in Washington, D.C., says Canadian scientists have not yet reviewed the EDF study. Still, he says, "It is one more study, one more piece of information showing a new element of the problem. And it cannot but help reinforce the need for action."

A House committee staffer agrees. The environmental group's findings "affect a different constituency—people who like to sail and fish—so they broaden the community of interest." He adds that the "potential political implications are very significant, but it's too early to say what they might be."

Some Congressional observers say the report's conclusions put added pressure on Congressmen representing states that are part of the Chesapeake Bay's watershed. Senate majority leader Robert C. Byrd (D.-W.Va.), to the frustration of many of his Democratic colleagues, has prevented acid rain legislation from reaching the Senate floor. He has done so because he represents a state that would have to severely control electric power plant emissions, a state with a major coal mining industry. The problem is that West Virginia coal is high in sulfur, which contributes to acid rain. The senior Senator from Virginia, Republican John W. Warner, has voted against acid rain control legislation. EDF's report could force Byrd's hand in bringing bills to the floor, and could compel Warner, whose state borders the bay, to vote for the measure.

A lot of the resistance to control measures is economically based. As Prime Minister Mulroney noted in his address to Congress: "I will admit without hesitation that the cost of reducing acid rain is substantial, but the cost of inaction is greater still."

The Congressional Research Service and EPA have analyzed the costs of compliance with the acid rain provisions in S. 1894, introduced by Sen. George J. Mitchell (D.-Me.) and currently awaiting floor action in the Senate. Depending on the baseline chosen for analysis, CRS pegs the cost of Mitchell's acid rain provisions at $0 to $8 billion per year by 2000. For example, if EPA, as it has the authority to do under the current Clean Air Act, implements more stringent sulfur dioxide and nitrogen oxide standards, then the cost of complying with Mitchell's bill would be $0 per year. If, however, EPA fails to modify its clean air rules to implement stricter regulations, then the cost of complying with Mitchell's bill would be $8 billion. EPA estimates, using two different models, range from $2 billion to $14 billion per year by the year 2010.

Larry Parker, CRS specialist for energy policy, says that "EPA's costs for the year 2000 are the same as CRS's—$6 billion to $8 billion per year—if existing Clean Air Act regulations remain in place until 2000." EPA, however, projects to the year 2010. "We think projecting to 2010 is stretching the analysis," Parker says.

Industry analyses tend toward the upper end of EPA's estimates. But they, like EPA, fail to calculate the benefits from controlling acid rain. CRS estimates benefits at between $5.5 billion and $8.2 billion, mainly to urban areas. □

Japan sets up program for biological research

Japanese officials have put final touches on plans for a global biological research program, called the Human Frontier Science Program, that they hope will launch their country into a new era of international science. Japan will establish a nongovernmental secretariat for the program and will manage it through an international governing council. Almost all the funding in the countries involved—Japan, the U.S., Canada, and the European Community countries—will be provided by Japan, at least at first.

In its present design, the program consists of two thrusts—one in the neurosciences with emphasis on brain function, the other on the chemistry and molecular biology of gene expression. The program in the first year would consist of 30 to 50 direct research grants to researchers working in teams, 100 to 200 postdoctoral fellowships, and 10 to 20 workshops. Young researchers would be favored for funding. The average annual grant size would total $500,000, and postdoctoral awards would average $50,000.

Although the sums are minor as far as international programs go, the Japanese have ambitions for the program that project far into the future. In their final document—issued last month—they see the program as creating "a new science and technology system based on complete harmony between nature and mankind." They hope the program's results will form the bases of revolutionary information technologies and techniques for disease prevention and treatment. The ultimate conceptual goal, however, is to relate molecular phenomena to the functioning of entire organisms.

The Japanese are eager to have the program placed on the official agenda for formal discussion at the economic summit meeting next month in Toronto. Although American sources believe it will not receive that much prominence, the seven heads of state are expected to at least sanction the idea. Some sort of official boost, the Japanese feel, will be needed for their Finance Ministry to approve funding of $40 million for the first full year, beginning in 1989.

The Japanese believe the program is also the key to Japan's new international thrust in basic research. It has been the official economic and scientific policy of Prime Minister Noboru Takeshita's administration to end its almost total reliance on the West for progress in basic research and to transform Japan into an international research power in its own right.

Japan—specifically the Ministry for International Trade & Industry (MITI)—has been trying to shape such a program for the past three years and has called on Western science leaders for help. MITI's early plan included not only brain function and reproductive science, but also immunology, endocrinology, aging, all aspects of metabolism, and in the early plan's words, "integration of various functions."

Kingsbury: open international activity

Funding estimates ran to $600 million for a single year; spending comparisons were made to America's Strategic Defense Initiative. But it also sowed distrust in the West and some infighting between MITI and Japan's Science & Technology Agency, which had its own Frontier Science Program, much smaller in scope but also international in purpose.

Western countries, Washington sources say, didn't like the idea of MITI funding it. Not only did MITI not have any biological research facilities of its own (except for a fermentation research center), but it also had a sullied reputation in the West as the agency that targeted Western technologies for defeat on the commercial battlefield. MITI, it was feared, would raid biological and pharmaceutical laboratories in the West just as it did the electronics research field, essentially monopolize the new era of drug therapy, and as a bonus apply Western brain research to commercial developments in artificial intelligence.

So when the Japanese encountered Western cynicism, they regrouped and took a more modest tack. They assembled an international feasibility study group to design a more attractive model. Discussions between the Japanese and Western scientists have been pro-

Improved Science Education Is Goal of Revived NSF Education Unit

After having been eliminated by budget cuts in 1982, reconstituted education directorate is back at work on key education programs

Pamela S. Zurer, C&EN Washington

Science education has come back to life at the National Science Foundation. Pruned back sharply just a few years ago, the agency's directorate for science and engineering education had gone dormant. Now, carefully nurtured by its energetic assistant director, Bassam Z. Shakhashiri, and well fertilized by Congress, education programs are flourishing again.

In the spring of 1982, with the budget-cutting Reagan Administration choosing to concentrate on funding basic scientific research, NSF abolished its education directorate. The agency all but abandoned its support for science education, which had been a major mission since NSF was launched in 1952.

Educational programs—which in the panic years after the Soviet Union launched the satellite Sputnik accounted for close to half of the agency's funds—were whittled away to nothing. Only an office of scientific and engineering personnel and education remained, charged with administering graduate fellowships and awards.

But, amid growing feeling that the future of the U.S. was threatened by the weak state of U.S. education in general, the directorate for science and engineering education was re-established in the fall of 1983. The directorate's budget since has been growing even faster than that of NSF as a whole. This year the education directorate accounts for about 8% of the total NSF budget, about the same share it commanded in the late 1970s. Congress appropriated $139 million for science and engineering education in fiscal 1988, an increase of 41% from the previous year and $24 million more than the Administration requested.

Shakhashiri came to the directorate in 1984 from the University of Wisconsin, Madison, where as chemistry professor he founded the Institute for Chemical Education. He believes fostering good science education for those students who will not become scientists or engineers is just as important a goal for NSF as is ensuring a good supply of technically trained people.

"In my opinion, the situation we face now in this country is more critical and more consequential than what we faced in the immediate post-Sputnik era," Shakhashiri says. "We now live in a much more advanced scientific and technological society than we did 30 years ago. It's the education in science and in technology of the nonspecialist that we have to pay attention to. We need an enlightened citizenry that can tell the difference between astronomy and astrology. We need a citizenry that understands the beneficial uses of chemicals, that does not associate the word chemical with something bad."

Shakhashiri points to a recent international science achievement survey as evidence that U.S. science education is in sad shape. Students at the fifth, ninth, and 12th grade levels in the U.S. performed poorly in science subjects in comparison with children in other countries.

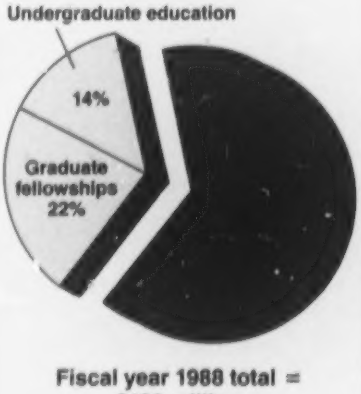
"I think this is a very, very dismal situation," Shakhashiri says. "I don't believe for one second that the raw talent in this country is any different than it is anywhere else in the world. Yet these data show that there are serious problems that we have to pay very strong attention to now—not tomorrow, or the day after tomorrow."

Accordingly, most of the growth in the education directorate during Shakhashiri's tenure has been in programs targeted at precollege education. "Those are the critical years when attitudes toward science begin to develop and to harden," Shakhashiri says. This year, roughly half of the $90 million precollege budget will be spent on high school projects and the other half directed toward elementary and middle school science education.

The directorate's precollege activities use two strategies. One approach aims at increasing the knowledge base and pedagogical skills of teachers, many of whom are inadequately trained in science. Another set of programs is directed toward developing curriculum-related materials to be used by students.

For instance, NSF has just awarded

Precollege programs lead NSF's education budget



Fiscal year 1988 total = $139 million

Source: National Science Foundation

Shakhashiri: Chemists must get more involved in education

C&EN staff photo

Bassam Z. Shakhashiri, head of the National Science Foundation's education directorate, feels strongly that scientists in general—and chemists in particular—should become more heavily involved in both formal and informal science education. Attracting more people into the sciences and fostering an appreciation for science and technology in nonscientists are crucial to ensuring a supportive environment for science in the U.S., he thinks.

"The educational reform movement of the past five years has resulted in a great deal of change," Shakhashiri says. "Many states now have increased their graduation requirements for science and for mathematics. But the scientific community has got to get into the act in a much stronger fashion to help define what the content is of those courses that have been put in place and how they can be taught better.

"We need to work very carefully in a collaborative way—that is, we the scientific community and the education community. We can't just say this is something the school of education has to face or the school system has to face. This is something that involves science.

"Why isn't there more discussion—or more action, not just discussion—on the part of chemists in terms of chemistry education? What does it mean to be chemically literate? Shouldn't the chemists get together and debate and decide what that means? Should it mean [simply] that people know the formula of sugar and the formula of sodium chloride? No, it shouldn't mean that.

"Chemists ought to take a very strong, aggressive stand on a variety of these issues. I think we—and when I say we, I mean the chemists—ought to take a very hard look at chemistry and how it's taught in schools and how it is taught in informal settings, whether it's museums or science centers or the media.

"You know how it is, the public does not use the word chemical by itself—it's 'toxicchemical,' one word. The public's perception of chemistry and chemicals and chemists has got to be worked on by the chemists, not by somebody else. We live in a chemical world, yet the chemists are not as forceful as I think they ought to be in communicating chemistry to nonchemists.

"Looking at the national needs as they exist now, I'd like the chemists to take the lead and to plunge into these activities. I think the American Chemical Society and chemistry in general should exercise a great deal of leadership in this regard. It's the responsibility of the chemists because it is their chemistry, their science, that needs to be shared.

"ACS is a very large, very distinguished organization. Yet I'd like to see it improve a great deal in terms of the attention it pays to these kinds of problems. ChemCom [the ACS-developed Chemistry in the Community high school course that takes a nontraditional approach to teaching the traditional concepts of chemistry] is a very important project that we have supported. But it is the only curriculum development project. I'm a strong supporter of ChemCom; I think it will do a great deal of good. But it should not be the only effort. The chemistry community should not sit back and say, 'Aha, we've done our part.'

"National Chemistry Day was a great idea. Why don't we have National Chemistry Day every month? I know it takes a lot of effort to organize these activities, but part of ACS's leadership role is to provide platforms and forums for local sections and other groups to do the kinds of activities that need to be done.

"I want to be sure that the attitudes that chemists have toward chemistry are communicated to everyone. We've got to convey our sense of excitement and commitment that we feel so strongly about."

$7.2 million in four grants to develop new elementary school science materials. The program is designed to foster partnerships among textbook publishers, school systems, scientists, and science educators to improve content and provide more hands-on activities for students. Another $12 million for the projects is coming from the publishers involved, who will market the new curricula and set aside a share of the profits for training teachers in their use. The agency currently is soliciting proposals for a similar program aimed at middle schools, and next year will add high schools.

Other programs in the division of materials development, research, and informal science education are aimed at applying advanced technologies like interactive videodiscs to science teaching. The division also supports research into how certain concepts are learned and how they best can be taught, and it provides partial funding for the children's science and math television programs "3-2-1 Contact" and "Square One."

A new program in the division of research career development is aimed at giving secondary school students research experience in science, math, and engineering during summers and weekends. The $3.7-million "Young Scholars Program" will give more than 2500 high-potential students a chance to participate in ongoing research projects with academic or industry scientists.

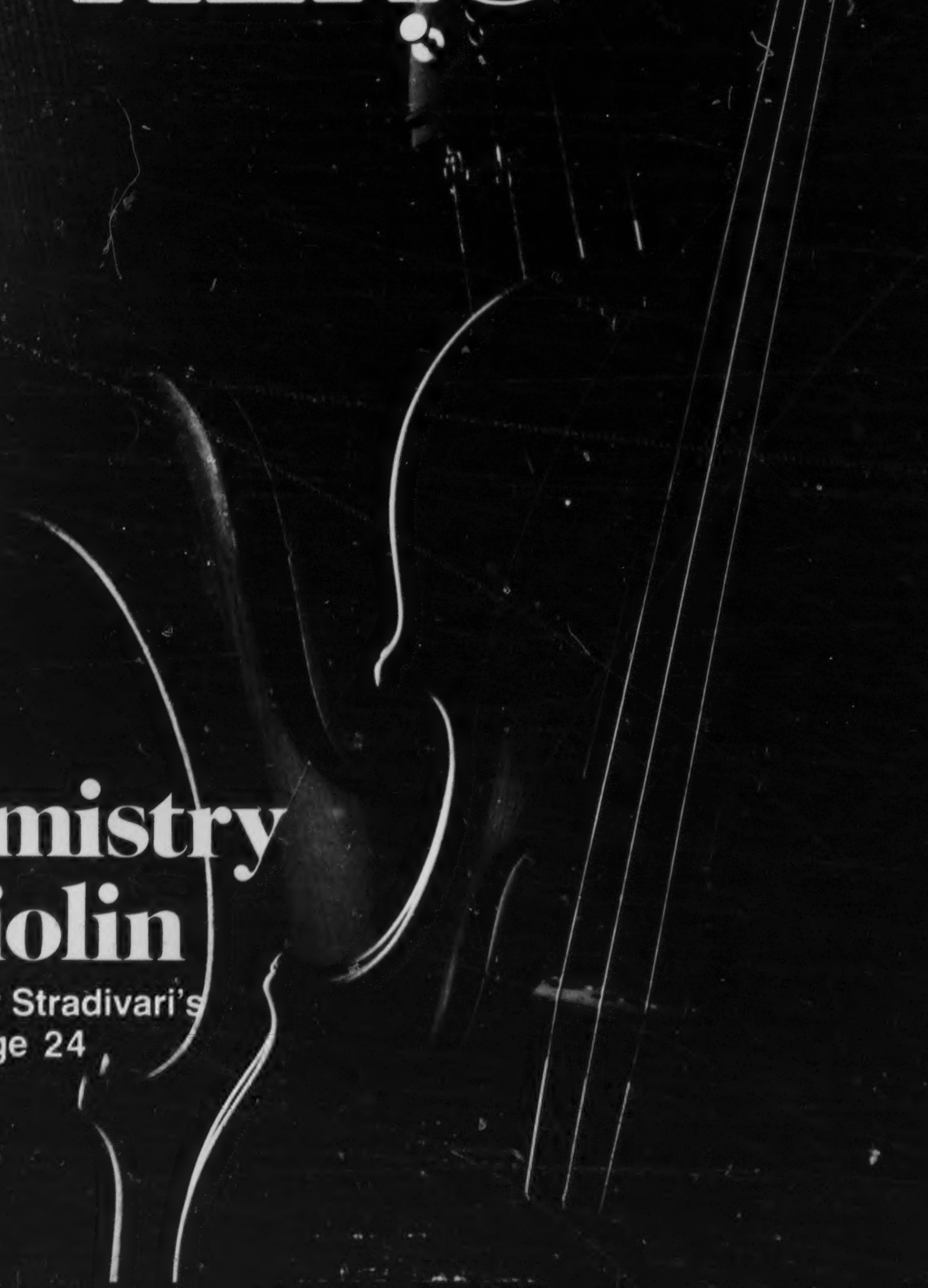
Other new NSF education programs are aimed at improving teaching and curricula at the undergraduate level and encouraging women and minorities to undertake careers in science and engineering. "NSF's role is one of leadership and leveraged support," Shakhashiri says. "We can't pay the bill for everything, but we can try to point the way to solutions." □

A1250-1
5/25/88

MAY 23, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR0621SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814



Chemistry and the Violin

Probing for Stradivari's secret Page 24

Volume 66, Number 21
CENEAR 66 (21) 1–48
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS

MAY 23, 1988

News of the Week

- **Surprise amendments to NSF's authorization bill would establish an investment banker role for the agency and put onus on the agency to ensure drug-free environments in the laboratories it funds.** Page 4
- **OSHA cites Hoechst Celanese for failing to provide a safe working environment at its Pampa, Tex., plant, where fatal explosions occurred last November.** Page 5
- **Health groups and their supporters in Congress launch new assault on tobacco industry after Surgeon General issues report that indicts nicotine as addictive drug.** Page 5
- **Soviets are expected to take part in NASA expedition, set for early '89, to probe Arctic stratosphere for signs of ozone depletion catalyzed by chlorine from CFCs.** Page 6
- **Du Pont's plan to give severance pay to its employees at the Department of Energy's Savannah River plant hits snags in Congress and with DOE.** Page 6

Cover: Photo by Lou Jones/
Uniphoto Picture Agency

Letters 2
Editor's Page 3

Concentrates
Business 7
Government 11
Science/Technology 14

The Departments
Meetings 32
Newscripts 48

Business

Chemical companies had significantly more cash last year as a result of rapidly increasing profits, a C&EN survey shows. **Page 9**

Government

Perceptions in Europe and U.S. of chemical risks differ, with Europeans more concerned about nuclear power, air pollution. **Page 12**

Pentagon's CBW research program has safety management problems, a Senate subcommittee finds. **Page 13**

Science

Research institute, headed by Thailand's Princess Chulabhorn, a Ph.D. chemist, aims to support country's development. **Page 15**

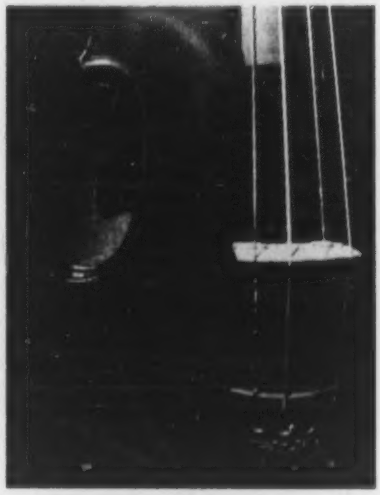
Education

Connecticut university's use of computerized lab management system marks move of software from industrial into academic setting. **Page 17**

Technology

International effort aims to design nuclear fusion reactor by the close of 1990. **Page 18**

Increased support for microgravity research on materials and materials processing is urged by NRC committee. **Page 21**



Special Report

Chemistry plays a role in the acoustical quality of the famous old Italian violins and may help unravel the secret of the classic string instruments. **Page 24**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholsón, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 47)

LETTERS

Nuclear energy

SIR: The letter of Miles Robinson (C&EN, April 11, page 5) provides proof of what many of us have long suspected: that medical education is insufficiently rigorous in analytical content, for even a modicum of research (with an open mind) and thought would show that compared to all other forms of energy, nuclear energy exacts the least cost in human lives and that we could afford a Chernobyl a year rather than accept the human loss involved in the extraction of equivalent amounts of fossil fuels.

High-level nuclear wastes can be stored in depositories whose lifetime is measured in hundreds of thousands of years to tens of millions before failure. Public aversion to nuclear power is a childish perception rooted in the technological ignorance of our public.

Walter E. Pittman
Professor, History of Science
Mississippi University for Women

Fossil fuel sources

SIR: In the discussion of atmospheric ozone depletion (C&EN, Aug. 17, 1987, page 7; Nov. 2, 1987, page 22) and the substances that may consume ozone, we are impressed by the omission of fossil fuel sources—and specifically coal. Some of our research findings show that percent levels of fluorine and chlorine are common in coal. Further investigations also showed that, although fluorine may be inorganically bound as fluorite (CaF_2), substantial amounts of fluorine are found in macerals (e.g., fusinite).

The organic affiliation of fluorine (and possibly chlorine) in coal leaves open the possibility that coal combustion (and possibly burning other fossil fuels) could contribute significantly to the anthropogenic fluxes of fluorine and chlorine to the atmosphere. Given the annual global coal combustion rate of 4 to 5 billion metric tons and a conservative fluorine level of 0.1%, then 4 to 5 million metric tons of fluorine could be released annually from coal burning.

In fusinite-rich coals organically bound fluorine has been observed as the dominant fluorine environment, and this could be an important source of coal-derived fluorine (and possibly of chlorine and chlorofluorocarbons). Assuming 10% of the total halogen component is organic, about 500,000 metric tons (5×10^{11} g) could be released each year during coal combustion.

We wish to underscore here the need for better monitoring of light halogen (i.e., F, Cl) levels in coal (including the phases with which they are associated), as well as for the fate of light halogens in the coal fuel cycle, especially where high-fusinite coals are being or could be used in the future.

J. R. Brown
Kanata, Canada
W. S. Fyfe
Faculty of Science, University of Western Ontario, London, Ontario, Canada
B. I. Kronberg
Geology Department, Lakehead University, Thunder Bay, Ontario, Canada

Health and nuclear power plants

SIR: Bernard L. Cohen (C&EN, Dec. 7, 1987, page 46) disputes my contention (C&EN, Oct. 19, 1987, page 2) that "misuse of public funds such as for 'protection' against natural low-level radon, is in great need of examination." He states, "If currently accepted (linear, no threshold) theories are correct, we are spending $2 billion per life saved from nuclear industry radiation, but only $4000 per life saved from radon exposure." Has he inferred causality from statistics? He also refers to a "waste of money trying to make nuclear power safe."

The linear, no-threshold hypothesis (ideology?) must be considered to be scientifically invalid on the ground that it is incompatible with observed data. It is also incompatible with extensive evidence on the reality of the biophysical phenomenon of radiation hormesis, as discussed in depth by T. D. Luckey [e.g., "Hormesis with Ionizing Radiation," CRC Press, Boca Raton, Fla., (1980); *Health Phys.*, **43**, 771 (1982); *Z. Phys. Med. Baln. Med. Klim.* (Sonderheft 1), **13**, 11 (1984); *Radiat. Res.*, **108**, 215 (1986)], and by R. J. Hickey and E. J. Bowers ["Physics in Medicine & Biology Encyclopedia," Vol. 1, McAinsh, T. F., editor, Pergamon Press, Oxford, U.K., page 387 (1986)]. Furthermore, H. L. Gjørup and H. J. M. Hansen (Health Physics Department, Risø National Laboratory, Roskilde, Denmark) reported, during a conference on health effects of low-dose ionizing radiation in London on May 11-14, 1987 ("Lifetime loss through lung cancer in Denmark and Sweden"), that although ^{222}Rn levels in homes in Sweden are about 2.1 times higher than in homes in Denmark, the loss due to lung cancer, 1972-78, was 2.0 times that in Sweden.

Earlier, in two press articles—one in

Continued on page 47

Chemical Companies' Cash Rose Markedly Last Year

However, inventories and receivables, as well as other day-to-day financing needs, also increased in 1987, C&EN survey indicates

William J Storck, C&EN New York

In these days of rapidly increasing corporate profits in the chemical industry, there is only so much that companies can do with the cash that they are receiving. They can increase dividends, they can use it to modernize plants, they can pay down debt, or they can hold on to it. And U.S. chemical firms seem to be doing all of these—but especially they are holding on to their money.

A C&EN survey of 20 U.S. chemical companies shows that the total of cash and marketable securities and current assets increased markedly in 1987 and current liabilities increased much more slowly. The result was increasing liquidity ratios for the firms.

The pattern among the companies is following that usually seen well into an economic recovery. The earnings momentum is providing cash for the chemical companies fast enough that they are having trouble getting rid of it. At the same time, however, current liabilities, the day-to-day financing needs of the companies, also are increasing. In fact, the only major component of financial obligation that declined for the companies in 1987 was short-term debt—a financing need that can quickly and easily be taken care of by cash on hand.

The larger cash amounts that companies had to work with in 1987 brought about something of an anomaly. Companies' two big cash drains are inventories and receivables, even though these two items are accounted for as current assets. When these increase, usually cash becomes short and short-term debt also increases. However, in spite of increases in inventories and receiv-

Cash and cash ratios increased last year

	1987			1986			1985			1982 (recession)		
	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio	Cash and marketables ($ millions)	Current ratio	Cash ratio
Air Products[a]	$ 96.6	1.3	0.22	$ 116.7	1.5	0.25	$ 46.2	1.3	0.09	$ 64.3	1.2	0.14
American Cyanamid	533.4	1.5	0.38	446.4	1.7	0.40	552.1	2.0	0.55	176.0	1.3	0.15
Dow Chemical	418.0	1.7	0.12	365.0	1.6	0.12	114.0	1.5	0.04	183.0	1.8	0.08
Ethyl	62.0	2.3	0.27	53.8	2.4	0.28	80.4	2.1	0.37	94.0	2.3	0.45
Georgia Gulf	24.2	1.8	0.24	3.2	2.0	0.05	1.2	1.1	0.01	na	na	na
B. F. Goodrich	110.9	1.4	0.22	51.9	1.4	0.12	58.9	1.2	0.07	44.9	1.6	0.09
W. R. Grace	151.4	1.5	0.13	92.5	1.3	0.08	151.6	2.0	0.15	164.5	1.7	0.17
Hercules	694.5	3.6	1.40	55.5	2.6	0.13	28.5	2.5	0.07	34.2	2.2	0.10
Loctite[b]	57.2	1.9	0.55	53.3	2.3	0.73	58.0	2.0	0.77	54.7	2.4	0.94
Lubrizol	92.7	3.0	0.55	85.6	2.8	0.53	63.0	2.5	0.35	25.4	2.7	0.22
Monsanto	223.0	1.7	0.12	274.0	1.6	0.16	293.0	1.4	0.12	414.0	2.6	0.44
Nalco Chemical	61.5	1.8	0.38	20.4	1.8	0.17	7.5	1.9	0.08	70.0	2.3	0.76
Olin	34.0	1.7	0.08	9.0	1.5	0.02	47.9	1.8	0.12	77.1	1.8	0.20
Pennwalt	53.4	2.0	0.21	60.6	2.2	0.29	58.4	1.7	0.21	14.7	1.9	0.08
Petrolite[c]	33.6	2.5	0.60	43.9	3.1	1.02	33.0	3.5	0.82	18.7	3.0	0.47
Quantum Chemical	24.9	1.4	0.04	87.3	1.1	0.08	47.3	1.5	0.09	141.1	3.5	0.60
Rohm & Haas	220.0	2.0	0.46	246.0	2.2	0.57	219.0	2.1	0.49	113.8	2.9	0.45
Union Carbide	201.0	1.4	0.11	299.0	1.3	0.16	459.0	1.3	0.15	154.0	2.0	0.09
Vista Chemical[a]	7.9	1.6	0.06	2.3	1.8	0.02	2.6	5.7	0.03	na	na	na
Witco	227.2	3.1	1.12	67.5	2.5	0.41	83.0	2.3	0.48	49.0	2.2	0.32
TOTAL (average for ratios)	**$3327.6**	**2.0**	**0.36**	**$2434.0**	**1.9**	**0.28**	**$2404.6**	**2.1**	**0.25**	**$1893.4**	**2.2**	**0.32**

Note: Current ratio is current assets divided by current liabilities. Cash ratio is cash and marketable securities divided by current liabilities. **a** Fiscal year ending Sept. 30. **b** Fiscal year ending June 30. **c** Fiscal year ending Oct. 31. **na** = not available.

Daily financing requirements rose in 1987

$ Millions	Inventories	% change 1987	% change 1986	Receivables	% change 1987	% change 1986	Accounts payable	% change 1987	% change 1986	Short-term debt[a]	% change 1987	% change 1986
Air Products	$ 127.0	−8%	0%	$ 289.9	−23%	−2%	$ 227.3	−12%	−1%	$ 21.1	−37%	−50%
American Cyanamid	676.8	17	−4	931.8	8	8	989.5	16	19	43.0	17	−86
Dow Chemical	1637.0	9	−26	2,269.0	32	−21	1583.0	34	−8	179.0	−36	−40
Ethyl	154.2	8	2	296.5	26	10	107.8	54	−15	0.8	6	−39
Georgia Gulf	54.8	−4	−21	95.4	26	0	55.7	23	−9	0	—	—
B. F. Goodrich	317.5	11	−28	264.4	1	−47	221.5	16	−33	53.7	−13	−77
W. R. Grace	629.5	12	−7	826.5	24	−5	521.1	21	6	148.4	−3	−48
Hercules	402.4	−12	5	698.6	23	−3	184.2	18	0	34.1	−51	−39
Loctite	50.4	19	19	85.0	28	43	20.8	33	34	36.6	103	−4
Lubrizol	206.2	7	−10	198.3	20	8	91.1	6	−6	13.6	215	−86
Monsanto	1081.0	1	−3	1,534.0	22	−22	527.0	15	−12	539.0	39	−45
Nalco Chemical	66.4	10	9	145.3	23	1	67.4	17	23	35.2	106	−19
Olin	273.0	3	−1	362.0	14	−2	200.0	17	4	50.0	−4	9
Pennwalt	195.2	22	2	206.5	7	−4	93.2	44	−15	48.6	0	−52
Petrolite	38.1	25	−29	56.0	15	−17	31.5	35	−12	15.5	41	142
Quantum Chemical	315.9	2	−26	434.1	8	19	133.5	1	23	114.0	−86	191
Rohm & Haas	309.0	0	−9	356.0	12	1	339.0	13	15	107.0	−3	−35
Union Carbide	827.0	11	−48	1,294.0	19	−34	559.0	35	−12	317.0	−31	−57
Vista Chemical	85.6	15	−2	101.9	16	7	41.7	−4	−3	20.9	−19	46
Witco	151.3	9	13	228.6	18	1	148.6	18	−2	4.0	9	−56
TOTAL	$7600.4	7%	−18%	$10,673.9	18%	−14%	$6142.8	21%	−2%	$1781.5	−32%	−35%

[a] Includes long-term debt payable within one year.

ables in 1987, short-term debt declined. Thus is the power of earnings-generated cash.

Analysts seem little worried about the increase in inventories last year since the companies do have cash on hand to finance them. Also, they point out, chemical companies, because of tight supply situations in many chemical markets, had been increasing inventories at the end of the year in anticipation of scheduled maintenance shutdowns this year. Since inventories, and indeed all balance sheet items, are measured at the end of the fiscal year, this may have tended to inflate the inventory situation.

For the 20 large chemical companies surveyed by C&EN, cash and marketables increased 37% in 1987 to a combined total of about $3.33 billion. It must be pointed out, however, that although an increase in cash is good, too much cash can be a large factor in making a company an attractive takeover candidate. If cash far outweighs the potential short-term needs for that cash within a corporation, then it potentially can be used to pay down acquisition costs of an acquiring company if the takeover is successful.

The large increase in cash among the companies was certainly helped by divested operations at a few of the firms. For instance, Hercules sold off its interest in Himont, which sent its cash soaring more than 12-fold to $695 million.

The large increase in cash and marketables last year also helped push up current assets. This balance sheet item increased about 14% in 1987 to end the year totaling $23.9 billion for the 20 companies. At the same time, however, current liabilities also increased, rising about 5.6% to end the year at a total of about $13.9 billion.

The result, however, was good in that the average cash ratio (cash and marketables divided by current liabilities) for the 20 companies was 0.36, up from 0.28 at the end of 1986 and up from 0.25 at the end of 1985. The average current ratio (current assets divided by current liabilities) at the end of 1987 was 2.0, up from 1.9 in 1986, but down from 2.1 at the end of 1985. The cash ratio last year finally was higher than the 0.32 scored at the end of recession year 1982, but the current ratio of 2.0 was still below the 2.2 seen at the end of 1982.

Except for short-term debt, daily financing requirements of the 20 companies rose last year. As a group, the companies' combined inventories increased 7% to about $7.6 billion at the end of the year, compared with an 18% decline the previous year. The firms' combined receivables increased 18% from 1986 to $10.7 billion, following a 14% decline in 1986. And accounts payable rose 21% last year to $6.14 billion, following a 2% decline in 1986.

Short-term debt at the end of 1987 declined 32% to $1.78 billion following a 35% decline in 1986.

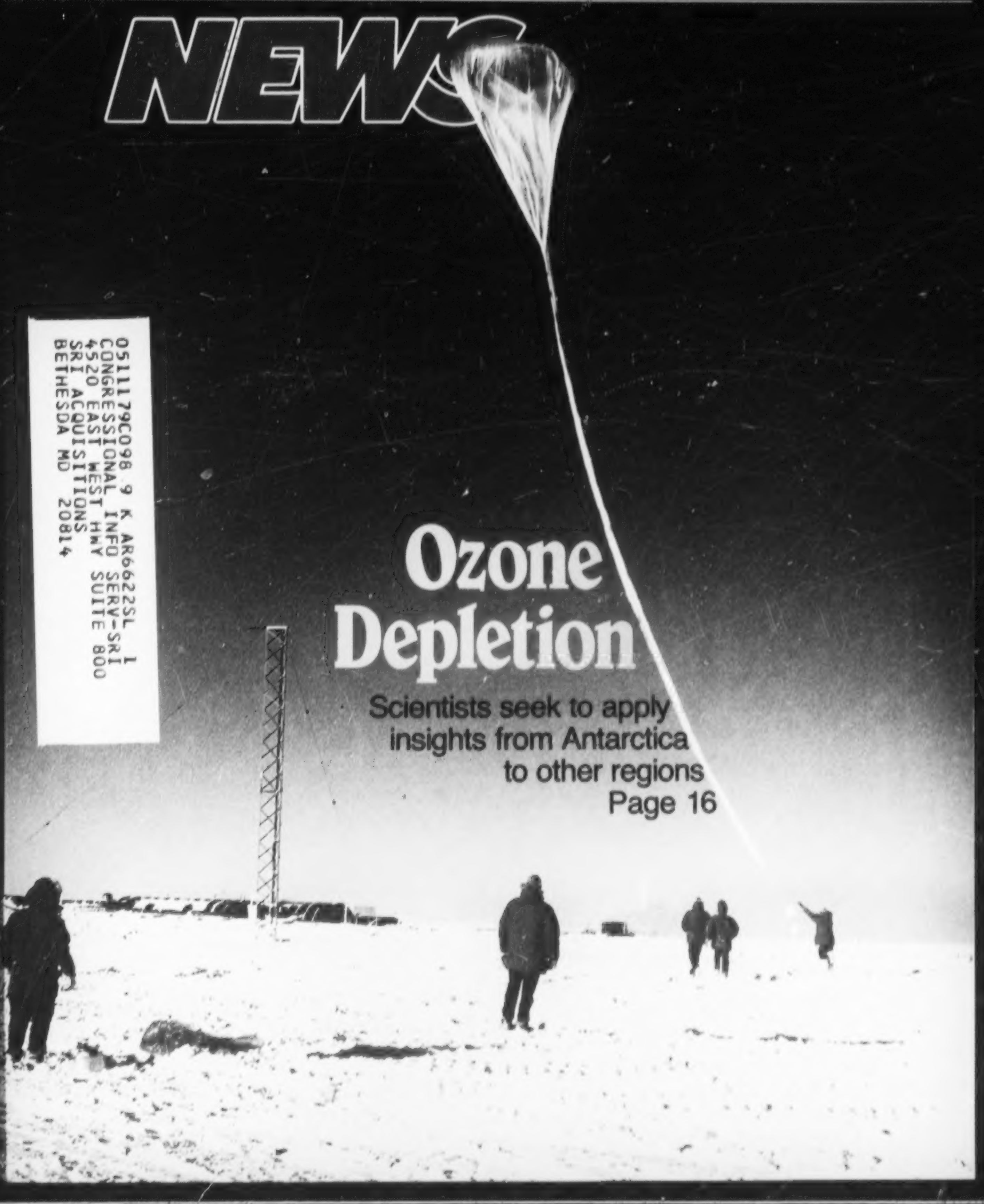
With all signs pointing to continued good earnings performance in the chemical industry for the next few quarters at least, the companies' cash on hand likely will continue to rise. Inventories probably will be drawn down as the industry enters the summer and uses stocks on hand during maintenance downtimes. Thus, the industry could well see at least some of the liquidity measures improving this year. Given the age of the current expansion phase of the business cycle, the industry probably will have lower current ratios even though the cash ratio may continue to expand. □

A1250-1
5/31/88

MAY 30, 1988

CHEMICAL & ENGINEERING

NEWS



Ozone Depletion

Scientists seek to apply insights from Antarctica to other regions

Page 16

0511179C098 9 K AR6622SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 66, Number 22
CENEAR 66 (22) 1–52
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS

MAY 30, 1988

News of the Week

- **Expanded cooperation in science and technology is expected to come out of the U.S.-Soviet summit this week in Moscow.** **Page 4**
- **Italy's two largest chemical firms—Montedison and EniChem—are moving toward linking their chemical businesses.** **Page 5**
- **UCLA's Richard B. Bernstein is the 1988 recipient of the Robert A. Welch Award in Chemistry.** **Page 5**
- **The Patent Office's efforts to fully automate have been strongly rapped by an industry panel and Commerce is acting to implement panel recommendations.** **Page 5**
- **Special luncheon held last week to hear the science views of the major Presidential candidates drew a tepid response.** **Page 6**
- **Argonne National Laboratory's electrorefining process is key step toward development of a nuclear reactor immune to meltdown.** **Page 6**

Cover: Researchers at South Pole launch balloon carrying ozone-measuring instruments. Photo by NSF's John T. Lynch

Letters 2

Concentrates

Business 7
Government 12
Science/Technology 15

The Departments

Books 34
ACS News 37
People 50
Newscripts 52

Business

Global consumption of alpha-olefins is expected to more than double to nearly 2.7 million metric tons in the year 2000, squeezing supply and spurring capacity additions. **Page 9**

Australia's giant liquefied natural gas project to be completed within year will launch the country as a major energy exporter. **Page 10**

Government

No links between Vietnam veterans' health and past exposure to herbicides in Vietnam were found in extensive new study by the Centers for Disease Control. **Page 13**

Fees for reviewing and processing pesticide registration applications will be implemented by EPA despite Congressional opposition. **Page 14**

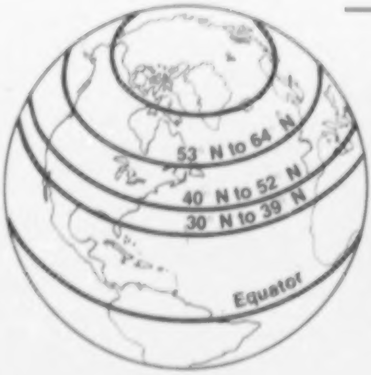
Education

Growing need for modernization and expansion is behind Institute of Paper Chemistry's decision to move to Atlanta by mid-1991. **Page 26**

Technology

In on-site analytical lab at Indianapolis 500 auto race, teams of chemists and technicians tested fuels and lubricants and examined auto parts for flaws. **Page 29**

New family of molecular sieves that are powerful deodorizers is developed by Union Carbide. **Page 30**



Science

Studies on ozone loss expand beyond Antarctica where chlorine from CFCs is proven culprit in ozone destruction as scientists find indications of perturbed chlorine chemistry in Arctic stratosphere. **Page 16**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 51)

LETTERS

Plastic handguns

SIR: Statements in the letter by Jack Jacox (C&EN, April 18, page 2) demand correction. He is apparently unaware of plastic handgun prototypes in existence in which the firing chamber and barrel are lined with carbon-fiber-reinforced high-impact ceramics. These guns have so little metal that they will not trip an airport metal detector. They will also be far cheaper to manufacture than machined metal weapons, so that national defense units have a legitimate interest.

For these reasons, it seems vital that strict controls be enacted to keep them out of the hands of terrorists—perhaps an impossible task.

Charles L. Levesque
Blue Bell, Pa.

Highly trained specialists

SIR: I scarcely blanched at the letter by Miles H. Robinson (C&EN, April 11, page 5), his remarks concerning "the shortsightedness of highly trained specialists" notwithstanding. He presumably intended to exclude broadly trained physicians such as himself from that categorization.

A problem did arise in my mind though, concerning his castigating the specialists' lack of vision with respect to the long-term impact of nuclear energy effects on biological systems. Without having, himself, the training of a specialist to judge it, he has no difficulty in rejecting technological solutions to waste containment. Has he considered the potential hazards of climatic change due to the higher global temperatures resulting from the greenhouse effect? Does his training enable him to judge the impact of economic and societal upsets on biological systems? Are such upsets less real than the effect of ionizing radiation?

New technologies must be poured over for risk possibilities, but not in isolation, as if existing methods were risk free. For example, what safer alternates are there to the use of nuclear energy, not only including alternate sources, but a shortfall scenario? What is the total impact on society within the range of possibilities?

Finally, Robinson chides us specialists for blaming the acceptance problems of nuclear energy on a public that is ignorant and uninformed compared to the "objective unemotional scholarly scientist." I believe the acceptance problems for new technology in general are due to a partially informed public. This is due in no small part to the lack of public relations and public affairs expertise of specialists such as ourselves, compared to the advocates of no change and status quo when it comes to issues related to the economic emergence of the have-nots of our world.

I can't avoid adding that I hope he remains so appreciative of the intuitive wisdom of the public as attention continues to turn to the exploding problem of affordable health care.

William S. Durrell
Chesterfield, Va.

Stereotypes of women

SIR: Upon receiving your detergent issue (C&EN, Jan. 25, page 21), we had some laughs in my lab about the absurd portrayals of the affinity between women and soap. It was refreshing to see a woman scientist on the cover for a change, even if the circumstances were dishearteningly stereotypical. The cosmetics issue (C&EN, April 4, page 21), however, is blatantly, repugnantly sexist. Once again there are women on the cover, but this time there is not even a pretense of their being scientists, or indeed anything more than objects.

First, depictions of women on the cover and in the magazine should acknowledge their diverse accomplishments, not focus on narrowly conceived notions of what women are and can do. Ads showing women should not suddenly pop out of the woodwork for an occasional woman-oriented issue. In the March 21 and 28 issues of C&EN, nine pictures of men and one picture of a woman appeared in the ads. The April 4 issue contained one picture of a man in an ad (for database search software), and seven pictures of women in ads (all for hair and skin care products).

Second, since products in the cosmetics and toiletries industry today actually

Correction

• May 2, page 8: Inadvertently omitted from the list of newly elected members of the National Academy of Sciences who are chemists or work in chemically related areas were Carl Frieden, professor and interim head of biological chemistry, Washington University; and John K. Hulm, staff member and director of corporate research and R&D planning, Westinghouse Research Laboratories, Pittsburgh

Demand for Alpha-Olefins Forecast To Double by Year 2000

Rapidly growing markets and shrinking supply is sparking capacity expansion plans in U.S. and abroad, as well as attracting new producers

Fast-growing end uses and capacity under strain: That's the recipe for a building spree. One of the most recent examples is alpha-olefins, the family of linear, one-double-bond olefins of various chain lengths, that serve markets ranging from comonomers for polyethylene to feedstocks for detergent surfactants.

Worldwide consumption of alpha-olefins is expected to more than double from 800,000 metric tons in 1986 to nearly 1.7 million metric tons in the year 2000, according to a new study by Colin A. Houston & Associates, Mamaroneck, N.Y.-based consultants.

With that kind of growth anticipated, producers Shell, Ethyl, and Chevron have launched major expansions in the U.S. and Western Europe. Ethyl is expected to announce soon a new 140,000 metric-ton-per-year plant, likely to be completed by the early 1990s, at its major plant site at Feluy, Belgium. Japanese capacity will more than double when Idemitsu enters the market with a new plant due on stream in early 1989. And Eastern European producers are planning or building alpha-olefin capacity—Czechoslovakia a 100,000 metric-ton-per-year plant, and the Soviet Union a 75,000 metric-ton-per-year unit, both slated to be on stream by 1991. And Shell is planning further debottlenecking of its facilities in the early 1990s.

End uses are almost completely determined by chain length. The light cuts, C_6 to C_8, have found solid markets as comonomers in making linear low-density polyethylene and high-density polyethylene. These end uses have been growing at about 25% per year, with the result that 1-hexene is in the tightest supply worldwide.

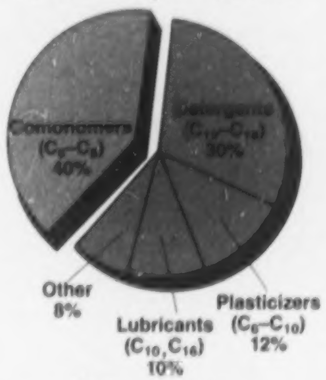
The importance of the comonomer market will continue to grow, predicts the Houston study. "Polyolefin comonomers accounted for just over 40% of total alpha-olefin consumption in 1986, and this will grow to 55% in 1995," says Ed Tarnell, director of special projects at Houston. "Use of alpha-olefins exploded with the development of linear low-density polyethylene in the 1970s. Exceptional growth will continue over the next decade."

However, he adds, consumption patterns for individual alpha-olefins, in particular, 1-butene, 1-hexene, and 1-octene, will shift according to regional supply availability and the impact of 4-methyl 1-pentene, a branched-chain olefin made by the catalytic dimerization of propylene, currently produced only by British Petroleum in the U.K. and Mitsui Petrochemical in Japan.

The heavier compounds, C_{14} to C_{18}, have markets in detergents, lubricating oils, and a variety of other products. For C_{16}, in particular, new markets are growing rapidly, putting pressure on supply of that particular set of compounds. Lube-oil additives are one fast-growing outlet, and paper sizings have been developed based on C_{16} alpha-olefins.

Some of that range also winds up in detergents, as alpha-olefin sulfonate. In Europe, the sulfonates have made very limited inroads. They are used for specialty formulations—baby shampoos, for example. The market in Western Europe is small, only about 3000 to 4000 metric tons per year.

Comonomers are biggest market for alpha-olefins



1987 total use = 800,000 metric tons

Sources: Colin A. Houston & Associates, industry estimates

On the other hand, Japanese producers have enthusiastically adopted alpha-olefin sulfonates for household detergents, replacing other surfactants. Similarly, there is strong development in these compounds in India, with a market currently at about 3000 to 4000 metric tons per year but predicted to grow within a few years to perhaps 30,000 metric tons. And the same fast-growth situation holds in South Korea.

The alpha-olefin sulfonates have found a place in Southeast Asia, says Shell's René Carlotti, business manager for detergents, higher olefins, and plasticizers at Shell International Chemical in London, because of the different washing conditions. The materials are particularly suited for toilet soaps and household soaps used under cold-water conditions. In Europe, where washwater would be warmer, different surfactants are needed.

In between the light cuts for comonomers and, to a lesser extent, plasticizers, and the heavier cuts, for detergents and other uses such as lube-oil additives, is the middle range. The hot "new" market there is for the C_{10} molecules for polyalpha-olefins, used in synthetic motor oils. These compounds have been around for a number of years, and have seen only slow development the past few years. Last year, however, the use of synthetic motor oils really started to grow, in part because of a move by marketers away from the purely synthetic product to blends, which offer improved performance without the full cost of the synthetic formulation.

The sudden growth probably has surprised the synthetic lubricant marketers; it certainly has surprised olefin suppliers. Says Carlotti: "We originally didn't plan to separate C_{10} from our production. Nobody expected a demand for it. But now the growth is there for polyalphaolefins, and people are believing in the development."

Houston's study points out that increasing alpha-olefin capacity will mean a greater availability of 1-decene, for synthetic lubricants, which in turn will boost that market. At present, the only commercial producers of polyalpha-olefins are located in North America, and tight 1-decene supplies have limited production and exports. However, new polyalpha-olefin capacity is expected in Western Europe and Japan by 1990, and in East-bloc countries by 1995.

Capacity for alpha-olefins to rise sharply by 1991

Thousands of metric tons per year	Current	Expansion	Completion date
U.S.			
Chevron	125	125	1990
Ethyl	400	55	1988
Shell	340	240	1989
U.K.			
Shell	220	50	1989
JAPAN			
Idemitsu	—	50	1989
Mitsubishi	35	—	—
CZECHOSLOVAKIA	—	100	1991
U.S.S.R.	—	75	1990
TOTAL	1120	695	

Note: Capacity for C_6 to C_{18} compounds. **Sources:** Colin A. Houston & Associates, industry estimates

Although some of the markets overlap at the edges of each of these cuts of alpha-olefins, basically there are specific sets of end uses for specific chain lengths. One of the major problems with the alpha-olefins business is that, although one can modify the distribution of the chain lengths, no process does away with any of them. If one or two are produced, all of them are produced, demand or not.

Each company's process tries to tackle this problem of chain-length distribution in its own way. For example, Ethyl says that, because its alpha-olefins plant is integrated with its primary alcohol plant and with the peaking technologies employed in the olefins plant, the carbon number distribution can vary toward the peaks desired. The company can, it says, peak its production toward the light, middle, or heavy end of the spectrum and within limits can peak individual carbon numbers, depending on demand of the marketplace. Shell, with its SHOP process, can recycle unwanted or unsold alpha-olefins to produce other olefins for detergent intermediates.

The answer to dealing with cuts that are in plentiful supply, in a time of tight supplies otherwise, lies in a philosophy of flexibility. Says an Ethyl executive: "We have built process flexibility into our Pasadena (Tex.) plant and will add more, which will allow us to produce those carbon numbers the marketplace demands and in the volumes required."

Ethyl has long stressed its flexibility in the merchant market. It claims to be the largest supplier of alpha-olefins in the world, with nearly 60% of the merchant market. Ethyl's strong dependence on the merchant market is unusual, points out the Houston study, because almost half the world's alpha-olefin production is used captively. For example, Shell, the largest producer, uses more than half its output to make oxo-alcohols. Ethyl, however, uses less than 10% captively, primarily for lube-oil additives and alkyldimethylamines.

Patricia Layman, London

Australia's huge LNG project nears finish

Within a year, construction of Australia's North West Shelf Project (NWSP) will be finished, and the Australians will begin shipping liquefied natural gas to Japan. This LNG shipment will mark the conclusion of what is said to be the largest chemical processing construction project in the world today. In addition to providing the domestic energy resource for most of Australia, NWSP will launch Australia as a major energy exporter.

The origins of NWSP go back to 1963, when a small petroleum company, Woodside Petroleum Ltd., obtained exploration permits to search for oil offshore in Northwest Australia. Woodside formed a joint exploration venture with Burmah Oil, Shell, British Petroleum, and Calasiatic, and drilled 13 wells between 1964 and 1972. In 1971–72 major gas fields were found in the North Rankin, Goodwyn, and Angel fields of the Dampier Sub-Basin off the North West Shelf of Australia.

Changes in the partnership occurred in the 1970s when the character of the resource was established. At present, NWSP is owned jointly by Woodside (50%), Australia Pty. ($16\frac{2}{3}$%), California Asiatic Oil Co. (Chevron) ($16\frac{2}{3}$%), Shell Development (Australia) Pty. ($8\frac{1}{3}$%), and Hematite Petroleum Pty. (BHP) (8 $\frac{1}{3}$%).

So far, 74 exploration wells and 12 field appraisal wells have been drilled. The result has been the discovery of proven recoverable hydrocarbons currently estimated to be 30.1 trillion standard cubic feet of natural gas and 542 million barrels of condensate in eight reservoirs of the Dampier Sub-Basin and the Browse Basin.

To an economy that had depended, in large measure, on imported oil for energy, the discovery of gas off the North West Shelf proved to be a boon, even if it did require some abrupt changes of technology to accommodate it. Development of the resource was helped along by the energy crises of the 1970s, which also prompted eventual development of the offshore gas fields of

A1250-1
6/8/88

JUNE 6, 1988

CHEMICAL & ENGINEERING NEWS

05111179C098 9 K AR6623SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814
2

Membrane Separation

Development activity targets high-volume industrial uses
Page 7

Volume 66, Number 23
CENEAR 66 (23) 1–52
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

JUNE 6, 1988

News of the Week

- **Two independent reports issued last week on the AIDS crisis recommend legislation to ban discrimination based on HIV infection and other federal policy moves to combat the disease.** **Page 4**

- **W. R. Grace pleads guilty to supplying false information to the Environmental Protection Agency on the amount of acetone it purchased and used at its Cryovac Division plant in Woburn, Mass.** **Page 5**

- **Bilateral agreements that expand cooperation in science and technology were announced at last week's U.S.-Soviet summit in Moscow.** **Page 5**

- **Koppers, a Pittsburgh-based construction materials and chemicals producer, accepts a $1.8 billion bid from British construction firm Beazer.** **Page 6**

- **Cotton fibers are grown in solution from isolated cotton plant cells; the product may have commercial potential as microbe-free fiber for specialty applications.** **Page 6**

Cover: Air Products Separex membrane gas separation system installed at a natural gas production facility in Louisiana

Letters 2

Concentrates

Business 17
Government 21
Science/Technology 24

The Departments

Meetings 33
Awards 50
Newscripts 52

Business

Revenues continued to climb for many biotechnology firms in the first quarter on the strength of research contracts and higher product sales, but most companies have yet to turn a profit. **Page 19**

Government

Controversy besets USDA's Agricultural Research Service over the appointment of its new administrator. **Page 22**

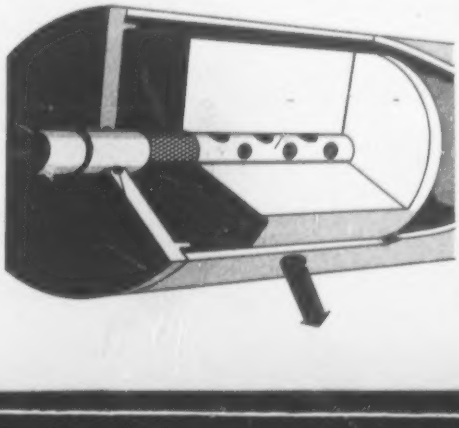
Technology

Process for injection molding of magnesium alloys, which resembles injection molding as practiced in the plastics industry, is developed by materials scientists and engineers at Dow Chemical. **Page 29**

New gallium arsenide solar cell converts sunlight to electricity with 28.1% efficiency, the highest conversion efficiency yet achieved by GaAs cell. **Page 30**

Books

"**Nothing To Lose but Our Lives:** Empowerment To Oppose Industrial Hazards in a Transnational World," edited by David Dembo et al., is a collection of critiques of U.S. chemical industry safety. **Page 31**



News Focus

Major breakthroughs in the development of membrane materials have led to the commercialization of a new generation of membrane separation systems for large-scale industrial applications. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 51)

LETTERS

Investigating AIDS

SIR: In the article by Rudy M. Baum, "Research on AIDS Moving Quietly Forward" (C&EN, March 28, page 29), the reference to the work and opinions of James I. Mullins and Jay A. Levy, as related to acquisition of AIDS via intestinal human immunodeficiency virus (HIV) infection, brought to mind a possible mechanism to explain the spread of AIDS by anal sex intercourse, not mentioned in any reports I have seen on the subject. This mechanism is that the mucolytic enzyme factor (hyaluronidase) in sperm cells, employed for penetration of the ovum surface in fertilization, may abet the HIV infection through its penetration of the mucous coating and cell surfaces of the intestine.

A simple animal test of the mechanism of infection might be anal introduction of hyaluronidase in a suitable solution into the lower intestinal tract with and without HIV, and also of a solution of the HIV without the enzyme. The effect of accompanying such tests with rubbing the mucosal surface, in simulation of anal intercourse, may be unnecessary, as Levy, in the article cited, discounted these friction or trauma factors in the infective process.

Having been retired from laboratory work for some time I am not in a position to undertake this study, but I offer these suggestions in the hope that they will be investigated.

David Glick
Professor Emeritus, Pathology
Stanford University

Technology free trade

SIR: The article, "U.S., Japan Approach New Era in Science and Technology Relations" (C&EN, April 11, page 13), correctly points out that the society and culture of the U.S. promotes creative research, whereas the authoritarian culture in Japan sustains excellence in product development and commercialization. Unfortunately, free trade between the U.S. and Japan has resulted in a loss by the creative culture (the U.S.) of its manufacturing base.

Naturally, if our nation loses enough of its manufacturing capacity to other countries, it will also lose its freedom of self-determination. And when that happens, we will lose the free-thinking culture that promotes creative research.

In order to protect our research and development institutions from eventual decline into technical mediocrity, our nation must aggressively defend intellectual property rights, and tax the export of technology from our nation. By restricting the flow of technology, we will keep more of the technical resources that our culture spawns and that vitalize domestic manufacturing.

Although the present, unbridled export of technology might appear to be a boon to our R&D institutions, our technical leaders must acknowledge that over the long haul, the free trade of technology undermines the wellspring of our R&D capabilities.

Robert Fireovid
Justice, Ill.

Quality chemists

SIR: John R. Wasson (C&EN, March 21, page 5) expresses several valid arguments concerning the employment problems facing U.S. chemists and the need for quality over quantity in our chemical professionals. His insights on the state of academic research on the university level are quite accurate, and his proposals, while likely to be viewed as elitist and nationalist, would aid in streamlining the system and in producing better-trained chemists to fill entry-level positions. However, much of Wasson's commentary also reflects a somewhat narrow-minded and self-serving bias.

Although it is true that professional chemistry is not where the bucks are, the field does indeed offer its own special rewards. It is, nonetheless, only human nature to want to perform in a job that best suits one's capabilities and stimulates one's interests, and to receive the best compensation possible for one's efforts. The chemical profession is right in wanting the best and brightest for its ranks; unfortunately in many instances the system that seeks to produce them instead discourages aspirants to the fold. The current publish-or-perish mentality in academe requires maximum results from a professor's research efforts in order to ensure tenure and increase the influx of grant money. Often this prevents professors from providing the supervision necessary to adequately train graduate students in advanced laboratory techniques, whether directly or via their postdoctoral associates. As a result, it is often the case that graduate research advisers seek students who have gained experience either in industry or in other graduate programs, either as transfer students or M.S.-level chemists. In turn, graduate laboratory assistants generally do not encourage their undergraduates to learn technique and to gain the insight necessary to under-

Revenues Still Rising For Biotechnology Companies

Research contracts and increased product sales bolstered revenues for many firms in first quarter; profits remain elusive for most firms

Research contracts continued to help biotechnology firms increase their revenues in the first quarter of 1988. And in some cases, most notably Genentech, product sales helped swell revenues and profitability well above the year-earlier results.

Combined revenue of the 18 companies sampled by C&EN increased 48% to a total of $198 million in the first quarter of 1988 compared with last year's first quarter. As a composite, the group registered a profit; combined earnings amounted to $2.3 million compared with a loss of $331,000 in the first quarter of 1987.

Many of the firms sampled are still actively in pursuit of the products and patents that they hope will ultimately make them profitable. Food & Drug Administration and Environmental Protection Agency approvals have allowed some to approach their goals.

In some cases, however, the most profitable companies have become victims of their own success. Genentech, the darling of publicly traded biotechnology stocks, has seen its stock price decline over the past year despite the successful introduction of its Activase tissue plasminogen activator, a blood clot-dissolving agent used to treat heart attack victims. According to Linda Miller, an analyst with Paine Webber, the success of Activase has overshadowed Genentech's other major pharmaceutical products, such as human insulin, human growth hormone, and α-interferon.

Genentech is thus "viewed as a one-product company," says Miller, and "is now valued in comparison to other pharmaceutical companies." But without the earnings or visibility of other pharmaceutical stocks, Genentech, which has "a superior rate of growth, is receiving a discounted value in the market."

The firm's Activase may have some problems, too. Because it now costs $2200 per dose, some analysts note that government resistance to paying the full cost of the drug under Medicare may limit the drug's earnings potential. "They may have to reduce the price," points out David Webber, an analyst with Jeffrey Casdin & Co. "Most people," he adds, "were disappointed with [Genentech's] first-quarter sales and feel they have not increased tremendously."

Genentech's chief executive officer Robert A. Swanson counters that "At the beginning of the quarter, approximately 1000 patients per week were receiving Activase for the treatment of heart attacks. By the end of the quarter, that number had doubled." He adds: "We are pleased by the exceptional clinical effectiveness of Activase."

Of the $74.4 million in total revenues Genentech reported in the first quarter, $63.5 million was from product sales. In last year's quarter, Genentech had product sales of only $16.5 million out of total revenues of $38.6 million. Genentech's prod-

Revenues up an average of 48% for 18 biotech firms

	FIRST-QUARTER 1988					
	Revenues[a]	Earnings[b]	Change from 1987		Profit margin[c]	
	($ millions)		Revenues	Earnings	1988	1987
Amgen	$14.573	$0.488	37%	110%	3.3%	2.2%
Applied Bioscience	10.431	0.883	50	44	8.5	8.8
Applied Biosystems	37.323	5.135	74	149	13.8	9.6
Biogen	6.747	−0.935	60	def	def	def
Calgene	9.163	0.044	25	−88	0.5	4.1
Centocor	15.721	1.993	31	29	12.7	12.9
Cetus	16.610	−6.974	22	def	def	def
Collagen	7.512	−0.664	12	def	def	11.6
Cytogen	1.792	−3.125	−29	def	def	def
DNA Plant Technology	1.540	−0.355	−15	def	def	def
Genentech	74.424	15.211	93	235	20.4	11.8
Genetics Institute	2.630	−5.993	−50	def	def	def
Immunex	5.155	0.596	44	def	11.6	def
Integrated Genetics	3.436	−0.923	1	def	def	4.0
Liposome	1.518	−0.550	69	def	def	def
Molecular Genetics	1.421	−0.384	−36	def	def	def
Ribi ImmunoChem	0.339	−0.468	−21	def	def	def
Synergen	1.749	−1.160	−22	def	def	3.6
TOTAL	$197.511	$2.311	48%	def	1.2%	def

a Includes sales, contract research, royalty, and interest revenues. b Excludes extraordinary and nonrecurring items where possible. c After-tax income as a percentage of sales. def = deficit.

uct sales have grown 285% while total revenues have grown only 93%. Total earnings after taxes have grown a spectacular 235% for the company—proof of the kind of profits a "blockbuster" biotechnology breakthrough can help a company realize.

Amgen, which may soon receive FDA approval to market erythropoietin (EPO), a product that enhances the production of red blood cells and thus is used for treating certain types of anemia, may come under product price resistance similar to Genentech's experience with Activase. Webber says he estimates EPO's average annual cost per patient at $2000 and thinks the company also may have to reduce the estimated price of its product, making for a longer period to recover development cost and cutting into profit potential.

For the moment, though, Amgen is among the profitable biotechnology companies in C&EN's survey. Its revenues, mostly derived from research contracts, totaled $14.6 million in the first quarter, up 37% from last year's first quarter. Earnings climbed 110% to $488,000.

Amgen chairman, president, and chief executive officer George B. Rathmann is sanguine about the company's successes so far. "We have advanced each of our major product programs closer to the marketplace, continued to pursue an aggressive program of new product discovery and development while still maintaining a strong financial profile. We look forward to continued success as Amgen establishes itself as a leading contributor to the biotechnology industry," he says.

One biotechnology company reported strong first-quarter earnings for an unusual reason. Applied Bioscience president and chief executive officer Kenneth H. Harper says that about half of the company's earnings boost came from currency translation gains due to the appreciation of the British pound against the U.S. dollar. Applied Bioscience is the parent company of Bio/Dynamics of East Millstone, N.J., and Life Science Research of Suffolk, England.

A number of biotechnology companies have found it difficult to secure new research contracts and financing since the October stock market crash. These firms continued to show losses because they were either funding more of their own research or were financing clinical testing of proprietary new drugs.

Larry Soll, president and chief executive officer of Synergen, says, "In line with our increased emphasis on self-funded programs, our spending for proprietary research and development more than doubled during the first quarter of 1988 compared to the same period in 1987."

Ribi ImmunoChem's president and chief executive officer Robert E. Ivy says the "increased loss reflects accelerated clinical testing to hasten our products to market." And Cytogen says that costs of an investigational new drug application for Onco-Rad, an antibody linking agent that aids targeted radioisotope treatment of tumors, represented significant operating expenses.

Marc Reisch, New York

Correction of chemical sales and earnings data

Some lines were inadvertently transposed in the 12-month running data that appeared in the table containing first-quarter sales and earnings results (C&EN, May 16, page 12). Below is the entire corrected section of the table, so readers may have a clear and comprehensive picture of company results.

	12-MONTH RUNNING DATA			
	Change from 1987		Profit margin[a]	
	Sales	Earnings	1988	1987
Air Products	11%	31%	8.4%	7.1%
American Cyanamid	10	23	6.3	5.6
Arco Chemical	30	79	14.7	10.6
Aristech	27	58	8.1	6.5
Betz Laboratories	15	18	10.4	10.2
Cabot	−6	−22	4.2	5.1
Chemed	1	17	5.2	4.5
Crompton & Knowles	5	44	5.3	3.8
Dow Chemical	24	85	10.5	7.0
Ethyl	14	9	11.0	11.6
First Mississippi	25	359	6.3	1.7
H. B. Fuller	21	36	4.1	3.6
Georgia Gulf	108	336	14.8	7.1
B. F. Goodrich	−2	189	5.0	1.7
W. R. Grace	27	def	3.5	def
Hercules	2	−4	7.4	7.9
International Flavors	21	27	14.6	14.0
International Minerals	4	def	5.3	def
Loctite	28	32	9.6	9.3
Lubrizol	6	−11	6.2	7.4
Monsanto	13	56	6.4	4.6
Nalco Chemical	18	44	9.8	8.1
Olin	17	60	4.1	3.0
Pennwalt	11	7	4.4	4.5
Petrolite	10	3	5.5	5.8
Quantum Chemical	21	169	7.8	3.5
Rohm & Haas	11	7	8.7	9.1
Union Carbide	12	69	3.7	2.5
Vista Chemical	28	52	12.1	10.2
Witco	11	14	4.9	4.8
Total 15 larger firms	**15%**	**61%**	**7.3%**	**5.2%**
Smaller 15 firms	**18%**	**67%**	**8.1%**	**5.7%**
GRAND TOTAL	**16%**	**62%**	**7.4%**	**5.3%**

[a] After-tax earnings as a percentage of sales. def = deficit.

NAS president Frank Press calls on science community to set its own priorities Page 27

A1250-1
6/14/88

JUNE 13, 1988

CHEMICAL & ENGINEERING NEWS

Plastics Additives

New products provide improved properties and processing
Page 35

0511179C098 9 K AR6624SL 17
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS
JUNE 13, 1988

Volume 66, Number 24
CENEAR 66 (24) 1–76
ISSN 0009-2347

News of the Week

- **Methyl isocyanate gas may have wider ranging systemic effects than previously thought.** Page 6
- **The 3rd Chemical Congress of North America attracted over 14,000 to Toronto last week.** Page 7
- **Researchers have confirmed that an oncogenic protein can directly control other genes.** Page 8
- **X-ray crystallographic studies reveal how new antiviral compounds bind to viruses.** Page 8
- **A new computer journal for organic chemists is being published by Pergamon Press.** Page 8
- **Concern grows about damage to U.S. space program from ammonium perchlorate shortages.** Page 9
- **The governors of New York and Ohio have agreed on a formula to limit acid rain emissions.** Page 9
- **OSHA is proposing a toughening of permissible exposure levels for 234 chemicals.** Page 10

Cover: Ethyl Corp. supplies brominated flame retardants for plastics from this Arkansas facility

Letters 4

Concentrates

Business 11
Government 16
Science/Technology 22

The Departments

New Products 53
Awards 61
Newscripts 76

Business

Emerging chemical trade in developing nations in Far East, Pacific Rim, other regions will present new challenge for industry, Shell executive predicts. **Page 14**

Government

Presidential contenders Bush, Dukakis, Jackson hold similar positions on domestic and global environmental issues. **Page 17**

Science Policy

NAS president Frank Press discusses need for science to set its own priorities, some key science and technology issues. **Page 27**

Technology

New type of LC/MS interface makes it possible to identify compounds not amenable to GC/MS determination. **Page 31**

Yale scientists are using electrospray ionization MS to determine high molecular weight proteins on a quadrupole analyzer with an upper mass limit of only 1600 daltons. **Page 32**

Education

ACS has published a sourcebook aimed at enlivening the content of undergraduate physical chemistry courses. **Page 34**

Books

"Petrochemicals: The Rise of an Industry" by Peter H. Spitz is an optimistic look at an industry with a dramatic past. **Page 58**

Product Report

Amount of additives used in plastics is declining as products that provide the same or improved performance at lower concentrations become increasingly available. Page 35

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager), Alan Kahan (Art Director), Barbara Fryer (Production/Art Director), Linda Mattingly (Staff Artist), Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign, more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 75)

LETTERS

CHEMICAL SAFETY

Di-*tert*-butyl peroxide

SIR: In the course of carrying out a routine undergraduate physical chemistry laboratory experiment, a violent explosion occurred. The experimental procedure was nearly identical to that described in the literature [Trotman-Dickenson, A. F., *J. Chem. Ed.*, **46**, 396 (1969)] for the gas-phase decomposition of di-*tert*-butyl peroxide. Our apparatus utilized a mercury manometer rather than a Bourdon gauge, but otherwise was identical to that of Trotman-Dickenson. In the past two years, our physical chemistry laboratory students have performed the experiment between 20 and 30 times with excellent results and no hint of danger.

On Thursday morning, April 14, 1988, a student completed his first run at 155 °C with normal results, according to his notes. A second run was initiated by injecting 0.2 mL of di-*tert*-butyl peroxide through a rubber septum into a 250 mL reaction flask at 165 °C. The student read the initial pressure on the manometer, turned his back to the apparatus, took three steps to his notebook to record his data, and the explosion occurred. Standing in my adjoining office about 12 meters away, I whirled around in time to see an orange fire ball floating toward the ceiling. The explosion blew hot oil, thermostatting the reaction vessel upwards toward the ceiling. A few drops fell upon the student causing minor burns on the back of his neck.

Although only 0.2 mL of di-*tert*-butyl peroxide was used, the explosion was violent and frightening to others in the room and to myself. The report was at least as loud as a 12-gauge shotgun. No errors on the part of the student were evident. If contamination was a contributing cause, it was not of the kind that could reasonably be controlled in an undergraduate laboratory situation. Consequently, we are discontinuing this experiment and would advise other users of di-*tert*-butyl peroxide in similar situations to do likewise.

Rodney J. Sime
Department of Chemistry
California State University, Sacramento

News on dioxin

SIR: Did I miss it? Or have you failed to note in your columns the important new report from the Air Force on agent orange ("United States Air Force Personnel and Exposure to Herbicide Orange" by Richard A. Albanese, M.D., Feb. 1988, USAFSAM-TR-88-3, available from USAF School of Aerospace Medicine, Human Systems Division, Brooks Air Force Base, Tex. 78235-5301), which indicates that Air Force personnel exposed to agent orange in Vietnam have suffered major health damage compared to those not exposed? The health damage includes a significant increase in the incidence of cancer, liver damage, cardiovascular disease, birth defects, and psychological change.

This report reverses findings of previous Ranch Hand studies (which received wide publicity in your journal and elsewhere) that indicated that there was no significant difference between those exposed and those unexposed.

Although Albanese's study is not definitive proof that dioxin is the causative agent for this human health damage, it should surely put an end to those complacent statements from so many government and industrial spokesmen who tell the public that while dioxin is incredibly toxic for a wide range of animal species, it appears to do little damage to human beings.

The wary should have been suspicious of humans being the beneficiary of such a biochemical miracle, especially when no mechanism was ever offered that would explain how humans escape dioxin's attentions.

Meanwhile, for those who wish to see the matter finally proved (one way or the other) it is critical that the government agencies investigating dioxin ex-

Correction

- May 16, page 14: In the pharmaceutical companies table, Abbott Labs' sales were $1.188 billion, not $219.3 million; earnings, $172.1 million, not $8.4 million, in the first quarter. Sales and earnings were up 18% and 22%, respectively, not 9% and 13%, in the first quarter; profit margins were 14.5%, not 3.8%, in the first quarter, and 14.1%, not 3.7%, in the year-earlier quarter. Bristol-Myers' after-tax earnings in first-quarter 1988 were up 21%, not down 25%, and its profit margin in 1987 was 12.9%, not 13.9%.

The diskette material will enable the reader to repeat demonstrations described in the paper, apply programs to his or her own work, and verify at once that the techniques perform as the author claims. Referees also will be able to review papers by actual use. Diskettes can be run on IBM PC and PS/2 or compatible microcomputers.

The new journal will publish papers, communications, reviews of research topics and of software, and news items. Papers will appear in as little as 90 days after submission, says organic chemistry professor Todd W. Wipke of the University of California, Santa Cruz, who will edit the journal.

Such rapid publication plus acceptance of communications that are shorter than full papers will let chemists see and use the work of others sooner than is now possible Wipke says. Too, chemists whose work is published in preliminary communications will be credited with inventing their techniques. At present, it often takes three years of work before results of a project are published.

Such rapid publication will be possible for papers submitted electronically as ChemText files, Wipke says. ChemText is a word and graphics processor that allows inclusion of texts and graphics in the same document. The program is published by Molecular Design, San Leandro, Calif., of which Wipke is a vice president.

Authors also may submit papers as typed manuscripts or electronically in a standardized format called ASCII. Institutional subscription prices will be $375 for the three issues of 1988, $750 for the six issues of 1989, or $750 for all nine issues of 1988 and 1989 if ordered all at once. Individual subscriptions will be $75.

Stephen Stinson, New York

Concern rises over rocket oxidizer supply

The U.S. may be facing a crisis in its space and missile programs over the next three years because of shortages of the solid fuel oxidizer ammonium perchlorate, warn members of Congress. But officials from the Department of Defense and National Aeronautics & Space Administration told a hearing last week that proper allocations, shifts and delays in programs, and building of new capacity should enable the nation to avoid any serious crisis.

"This country is on the brink of a national emergency," said Rep. Robert A. Roe (D.-N.J.), chairman of the House Science Space & Technology Committee and of its Investigations & Oversight Subcommittee. Roe was referring to the explosion early last month in Henderson, Nev., which leveled a Pacific Engineering & Production Co. plant, one of only two U.S. plants producing ammonium perchlorate (C&EN, May 16, page 5).

The plant was making 20 million lb a year of the perchlorate and had a capacity of up to 40 million lb. It was the principal supplier to the space shuttle program, and sole supplier for the Titan rocket and several military missiles.

The explosion killed two workers, injured hundreds of local residents, and destroyed much property in Henderson. Under local pressure, Kerr-McGee Chemical Corp. has shut down its perchlorate plant, also sited in Henderson, for safety checks most of the past month, idling its 36 million lb-a-year capacity. Local leaders have threatened suits to keep it closed.

A recovery strategy is being formed by an interagency group, with members from DOD and NASA and liaison with the departments of Commerce and Transportation. Detailed plans for rebuilding capacity, and for allocating production in the meantime, will be ready later this month.

The first step in recovery is to restart Kerr-McGee's production, and at press time the plant planned to reopen on June 13. Its capacity is also to be raised to 40 million lb a year. Then, with federal aid, Kerr-McGee and Pacific will build new plants with 20 million lb and 30 million lb annual capacities, respectively, but not in Henderson. NASA and DOD expect construction and qualifying to meet federal requirements to take about a year.

The interagency group expects that if all goes according to plan, all 1988 needs (38.8 million lb) can be satisfied, although schedules may be stretched out. And if expansion plans go ahead, it believes the shortfall in 1989 can be reduced to 3 million lb out of a demand of 60 million. Allocation plans will look at such steps as shifting some payloads from the shuttle (1.7 million lb of ammonium perchlorate per launch) to unmanned Titan IV rockets (800,000 lb per launch).

Subcommittee members were very skeptical of these projections, and will further question the plans at a hearing in a few weeks. "Let's not dance around it," says Roe. "We're in trouble."

Richard Seltzer, Washington

Ammonium perchlorate use in rockets to soar

Millions of lb	1988	1989	1990
Army	9.3	14.0	11.7
Navy	3.7	6.5	5.4
Air Force	11.0	11.5	16.1
NASA	8.5	19.8	22.1
Commercial space launches	3.5	3.7	5.2
EMLRS[a]	1.8	2.6	5.3
Other export	1.0	2.0	2.0
TOTAL	38.8	60.1	67.8

a European Multiple-Launch Rocket System. Source: Department of Defense

Ohio, New York agree on acid rain proposal

In a maneuver to break the Congressional deadlock over legislation to control acid rain, the governors of Ohio and New York have agreed on a formula to limit sulfur dioxide emissions from the combustion of coal, and nitrogen oxides from coal and other sources. Their proposal would come in the form of amendments to the Clean Air Act and could possibly speed acid rain legislation this year.

The agreement was about a year in the making and was signed by governors Mario M. Cuomo of New York and Richard F. Celeste of Ohio,

PRODUCT REPORT

Ethyl Corp. photo

Plastics Additives: Less Performing Better

Bruce F. Greek, C&EN Houston

Plastics additives, a complex and growing group of minerals and chemical derivatives, go into such a diversity of products that their outlook is hard to assess. Growth in use of additives, which often impart more than one property to resins, is lagging growth of plastics because of the increasing availability of additives that will provide the same or improved performance at lower concentrations. Demand for additives, however, is strong enough to spur many producers to expend money and effort to expand their lines and to build new capacity.

New additives for plastics continually come to market. They, along with existing ones, go into plastics at average rates slightly lower than in the past. The lower unit consumption results from constant improvement in the additives offered and improved plastics processing technology. Despite lower application rates, plastic products are fabricated with more processing ease and are increasingly well accepted by consumers. A significant concern about additives is their impact on the environment, particularly the disposal of additives that are in discarded plastic items and the health and safety of workers exposed to the additives during fabrication of the plastic products.

This year, about 10 billion lb of additives will go into more than 50 billion lb of plastic resins before the fabricated products reach the consumer, according to industry sources. No complete tabulation of the different additives used in plastics is available, but indications are that more than 4000 individual products exist. Many additives used in plastics also go into other consumer products, such as rubber, paints, and textiles. The use of additives in plastics is sometimes referred to as a "black art," because compounders rely on their own expertise in the application of additives to achieve desired properties and performance of the fabricated plastic item, sometimes quite without solid technical rationale. As a result, precise data on consumption of additives in plastics are not likely to become available. Most estimates are based on assumptions of an average use of functional classes of additives.

Three functional classes of additives—fillers, plasticizers, and reinforcements—account for about 85% of all additives used in plastics, estimates Freedonia Group, a Cleve-

← CIRCLE 35 ON READER SERVICE CARD

Several additives may be used in single plastic resin

	Antioxidant	Antistat	Catalyst	Flame retardant	Heat stabilizer	Impact modifier	Initiator	Lubricant & mold release	Plasticizer	Preservative	UV stabilizer
ABS	●	●		●		●	●	●			●
Acrylic		●		●		●	●	●	●		●
Epoxy				●				●			●
Nylon	●	●	●								
Phenolic				●				●			
Polycarbonate		●	●	●		●					
Polyester, unsaturated	●	●		●			●	●			●
Polyethylene, high density	●	●	●	●		●		●		●	●
Polyethylene, low & linear low density	●	●	●	●		●		●		●	●
Polypropylene	●	●	●	●		●		●			●
Polystyrene	●	●		●		●	●	●	●		●
Polyurethane		●		●						●	
Polyvinyl acetate		●		●	●		●		●		
Polyvinyl chloride	●	●		●	●	●	●	●	●	●	●
Thermoplastic polyester		●	●			●		●			

Note: Additives used in many of above plastics, but not indicated, include solvents, molecular weight controls, emulsifiers, blowing agents, fillers and reinforcements, colorants, and coupling agents.

land-based business database research firm. Those classes of materials, relative to resins, generally are chemically inert. Except for plasticizers, they also are unaffected by light, heat, and atmosphere. Another functional class, colorants (which accounts for about 4.5% of the additives used), also does not react with most resins.

The remaining 10% of plastics additives—the chemically reactive products—is dominated by flame retardants. Chemically reactive products also are used in plastics resins to impart longer life or improved performance to the fabricated products, to improve processibility of resins during fabrication, or to permit forms not otherwise easily attained without the additive. Another functional class of additives—the antistatic agents—gives ease in handling.

The outlook for use of plastics additives varies with the class of the material. The overall growth in demand for additives, of course, is linked to that of fabricated plastic products. And growth of plastic products will depend on how well they provide less costly or better substitutes for other materials through advances in polymer production and processing technology. The market for plastics additives, as a whole, will grow 3.5% to 4.0% annually over the next few years, industry sources forecast.

Use of some of the small-volume, chemically reactive plastics additives will grow faster than that for all plastics additives, according to Freedonia Group. Ultraviolet stabilizers, impact modifiers, and antistatic agents are examples of the faster growing groups of additives. Improvements in quality of these additives is an important factor in the higher growth rates. Better processing machinery and techniques also are fostering their use.

Government laws and regulations are both helping and hindering the growth of plastics additives. The increased requirements for flame retardancy in plastic building and construction products are spurring the use of flame retardant additives. But concern over the environmental impact of the additives (as well as resins) and concern for worker exposure during processing and fabrication of plastics where additives are involved are dampening the use of additives.

Plastics additives enter the environment via various routes, according to a study carried out by Radian Corp. for the Environmental Protection Agency and published by Noyes Data Corp., Park Ridge, N.J. During processing, additives may form volatiles (including aerosols) and particulates. Contact of those chemicals with water can lead to leaching and subsequently to possible contamination of water supplies. Volatiles and water contamination present potential problems when plastic products are burned or dumped in a landfill.

However, the environmental impact of additives in plastics is not always clear-cut, according to the Radian study. For example, many additives—such as colorants and fillers—are selected because they will remain in plastic resins. Others, such as phthalate plasticizers, exude from fabricated plastic products or are extracted by water or other solvents even if removal is not wanted or intended.

Plastic food packaging that contains additives must meet Food & Drug Administration guidelines, and the list of additives permitted for these uses is relatively short. These additives have low toxicity or are materials "generally recognized as safe" because experience has shown them to be so. Other additives that go into such plastic products as pipe, toys, furniture, and housewares are selected to limit the danger of exposure to them upon intentional or accidental contact.

The Radian report points out, however, that additives are but part of the impact of plastic products on the environment. Other factors include the resin containing the additive, conditions and methods of processing, use of the product, and the environment in which they are used and in which they are discarded. Future government regulations are likely to have a growing influence on additive choices.

Concern over worker exposure to additives more often involves the additives themselves rather than the compounded plastics, in which the additives are encapsulated into a relatively inert polymer, the Radian report points out. Possible hazards to workers are handled through normal safety and health procedures, most of which are those acceptable to the Occupational Safety & Health Administration, the report says. The trend toward custom compounding further reduces workplace hazards in plastics fabrication.

Coping with increasing regulations is one of the problems encountered by the several hundred companies who supply additives to the plastics industry. They also are coping with demands by resin compounders and plastics fabricators for ever better additives that will lower cost and improve performance of their final products. To meet those concerns, the industry has ongoing developmental programs that include fundamental studies on how and why additives work, on the process of bringing new products to market, and on reformulation of existing additives.

Recent commercial developments in plastics additives are exemplified

Additives vital to broad array of plastics

Additives improve the processing and performance of plastics and often have overlapping functional activities. Additives can be divided into four major areas of use, with each area containing subgroups of compounds having a particular functional activity. In these subgroups, a few compounds dominate use. However, many compounds may be used to obtain a particular function. Many other types of functional activity are obtained by additives not included in this list.

REACTION CONTROLS

Numerous chemicals used to control polymerization and other reactions overlap in their functions. Some are not true additives in that frequently they are absent in the fabricated products. If they are present in the final plastic products, they seldom have more than a minor effect on properties.

Catalysts are used in various ways in the polymerization process to make plastics. They differ from initiators in that they are not consumed, and, in the case of thermoplastics, generally do not become part of the polymers. Some catalysts are removed after polymerization. Hence, technically, they are not plastics additives. Others are left in the plastics because they have no significant effect on desired properties and because the cost of removal can be high.

Numerous catalysts now are used in making plastics, and the patent literature abounds with many more possibilities. Typical examples of catalysts used to make polyolefins (the various polyethylenes and polypropylenes) are metal oxides and the Ziegler-Natta systems containing aluminum alkyls and transition metal salts. Examples of catalysts to make thermosets (such as phenolics) are various acids and bases. Combinations of complex amines and organometallics (most often tin compounds) are examples of catalysts used in urethanes.

Initiators often replace or aid catalysts in polymerizations to produce polyvinyl chloride, the various styrenics, and other plastics. Peroxides—dialkyl, diacyl, and hydro—make up the largest share of initiators used commercially. Because initiators decompose to provide free radicals for reactive sites, their decomposition products become additives in plastics and may or may not be removed later.

Auxiliary processing materials frequently are tailored to specific polymerization processes and may be necessary to obtain the desired properties in a particular plastic. There are many examples of these materials, and they may be used in making just one or many polymers. Whether these materials or their decomposition products remain in the plastics depends on their usefulness and on subsequent processing of the plastics.

Solvents, one example of these auxiliaries, are widely used in making thermoplastics and are almost totally removed. Molecular weights of plastics are controlled by chain transfer agents, such as thiols; chain terminators, such as hydrogen and simple hydrocarbons; and crosslinking agents, such as divinylbenzene. Other auxiliaries are chemicals to control solution pH. Primary emulsifiers and secondary emulsifiers (protective gels) are required for emulsion and suspension polymerizations.

PROCESSING ADDITIVES

Various chemicals have been found to help processors make specialized forms of plastics. These chemicals also may speed processing.

Blowing agents are used to make foamed plastics. Polyurethanes account for more than two thirds of foamed plastics production. Physical blowing agents (about 90% of consumption) are liquefied gases such as chlorofluorocarbons (CFCs) and propane. (The continuing use of blowing agents that contain CFCs is in some doubt because of the current concern over ozone depletion.) Chemical blowing agents largely are complex derivatives of hydrazine. Many other chemicals, such as catalysts, surfactants, and nucleating materials, are used as auxiliaries to blowing agents.

Lubricants are added to plastics to promote resin fabrication and to improve properties of the final products. Compatibility with the resin most often determines which lubricant is used, although its ability to reduce melt viscosity and friction with metal surfaces is almost equally important. Compounds used as lubricants include esters, fatty acids, fatty amides, metallic stearates, waxes, fluorinated polymers, and silicones.

STABILIZERS

A large number of chemicals are used to minimize degradation of plastics by air (oxygen), heat, light, and microorganisms. Often the choice of stabilizer depends on the anticipated end use of the plastic. Frequently, different stabilizers are combined to improve resistance of the finished plastic product to

CIRCLE 44 ON READER SERVICE CARD →

degradation. Such combinations can impart other desirable properties to the plastic.

Antioxidants for plastics are classified as either primary or secondary. Primary antioxidants include various phenols and secondary amines that scavenge extraneous free radicals. Various phosphites and thioesters are used as secondary antioxidants (sometimes called synergists) that decompose peroxides (a source of free radicals). Many other compounds and proprietary mixtures are offered as antioxidants for plastics.

Heat stabilizers go mostly into PVC, with lesser quantities used in urethanes and some styrenics. Several of these materials also have secondary functions and may be combined with other functional compounds. Various metallic soaps, organotins, inorganic and organic lead salts, and tiny-volume specialty chemicals are used to confer heat resistance.

Light or ultraviolet stabilizers help plastics resist light degradation in several ways. Most of them absorb and/or quench the radiation. Others work similarly to antioxidants, by inactivating free radicals and peroxides. The most widely used light stabilizers are the benzophenones, which are light absorbers. Another important class of absorbers are the benzotriazoles. Organonickel compounds work as quenchers of UV light, and probably are second in use to benzophenones. A large number of other organic and inorganic compounds also are used as stabilizers.

Preservatives are used to fight microbial attack of plastics and additives such as plasticizers. Most are used in PVC, with lesser amounts in urethanes. They are typical bacteriocides and other biocides.

PERFORMANCE ADDITIVES

Performance additives usually go into polymers during fabrication of the finished products. They account, by far, for the largest volume of plastics additives, probably more than 75% of the total. Performance additives may be put into all kinds of plastics that become finished products, but a large volume of plastics is sold without any of these additives.

Fillers and reinforcements both lower the cost of a fabricated plastic product and improve its performance, usually without any chemical reaction with the polymer. These materials range from common clays to glass fiber. The concentrations of fillers and reinforcements in plastics vary widely and may exceed 20% in some plastics.

Plasticizers rank next to fillers and reinforcements in volume consumed in plastic products. PVC accounts for 80 to 90% of the consumption of these additives. Esters of phthalic anhydride dominate use, accounting for about two thirds of the total. Other important plasticizer groups are epoxidized soybean oil esters, adipic acid esters, trimellitic anhydride esters, phosphoric acid esters, and several kinds of resins.

Colorants are chosen from a huge selection of inorganic and organic pigments. Some impart additional properties—carbon black, for example, provides stability toward light. Most colorants are supplied in concentrated form for dispersion during processing.

Impact modifiers help fabricated plastics resist fracturing when stressed. Most have elastomeric properties. Many are acrylics or modified butadiene-styrene polymers, which usually contain acrylonitrile and methacrylate.

Flame retardants help plastics resist combustion. Various additives, especially fillers and reinforcements, affect a plastic's flame retardancy and, in turn, the amount of flame retardant needed in the plastic. There are different classes of flame-retardant additives. Inorganic compounds (particularly alumina trihydrate) are used in greater quantities than are organics such as various halogenated compounds and phosphorus derivatives. Some compounds, called reactive organic flame retardants, are polymerized into the resin.

Antistatic agents function by absorbing moisture from the atmosphere to provide surface moisture on plastics. The moisture dissipates the electronic charge often acquired from the atmosphere. Antistats may be added during compounding of plastics or applied after fabrication. Ethoxylated amines and quaternary ammonium salts account for most of the market, although many other chemicals are used as antistats.

Coupling agents typically are used in fabricated plastics to improve the physical bonding of fillers and reinforcements with polymers. Many different silanes are used with glass fiber and with inorganic fillers and reinforcements that contain silicon atoms. Organic titanium derivatives help bind nonsilaceous materials such as carbon black, metal oxides, calcium carbonate, and pigments to plastics. Numerous proprietary coupling agents are used in smaller quantities as binders. Many coupling agents provide various other functions.

by Ethyl's $100 million acquisition and expansion program for its line of flame retardants. Ethyl bought the majority of the assets and technology of Dow Chemical's bromine chemical business in 1987. Now the company is building a plant to make dibromoneopentyl glycol and related materials for use in rigid and flexible polyurethane foams and unsaturated polyester resins. Other new units and expansions will provide more capacity to make complex brominated- biphenyls and diphenoxybenzene and ethylene-(bistetrabromophthalimide). Ethyl has other units on the drawing board to make other additives.

Another additives supplier, Ampacet, is moving into statistical process control while expanding capacity to make its line of concentrates of additives for plastics. When expansions are completed at its Terre Haute, Ind., plant, Ampacet will have capacity of 100,000 tons per year from fully automated units to make its own color concentrates and concentrates of additives such as flame retardants, UV stabilizers, antioxidants, as well as combinations of additives and custom concentrates.

Borg-Warner Specialty Chemicals recently introduced a heat stabilizer for polyester resins and modifiers for PVC resins. The heat stabilizer is an organic diphosphite that has two functions during the melt-mixing process to fabricate the plastic for nonfiber uses. These are to deactivate catalysts remaining in polyethylene terephthalate after in-

← CIRCLE 44 ON READER SERVICE CARD

Overall amount of additives in plastics is declining

Millions of lb	1977	1987	1992	2000	Annual change 1977–87	Annual change 1987–92
Fillers	3,621	5,566	6,630	8,350	4.4%	3.5%
Plasticizers	1,418	1,694	1,835	2,045	1.8	1.6
Reinforcements	615	893	1,140	1,600	3.8	5.0
Flame retardants	362	513	665	905	3.5	5.3
Colorants	278	438	525	685	4.7	3.7
Impact modifiers	57	130	160	200	8.6	4.2
Lubricants	77	96	115	150	2.2	3.7
Heat stabilizers	85	83	91	102	−0.2	1.9
UV stabilizers	4	7	9	13	5.8	5.2
Antioxidants	26	42	50	60	4.9	3.5
Organic peroxides	34	44	54	70	2.6	4.2
Chemical blowing agents	13	13	15	18	—	2.9
Antimicrobial agents	6	11	14	18	6.2	4.9
Antistatic agents	4	8	10	13	7.2	4.6
Urethane catalysts	4	6	7	9	4.1	3.1
Others	39	104	130	172	10.3	4.6
TOTAL ADDITIVES	6,663	9,666	11,450	14,450	3.8%	3.4%
TOTAL PLASTICS	30,505	49,862	61,000	80,600	5.0%	4.1%
LB OF ADDITIVES PER 100 LB OF PLASTIC	21.8	19.4	18.8	17.9		

Source: Freedonia Group

itial polymerization, and to retain color and strength properties during processing. The stabilizer also improves color and other properties of recycled polyester, according to Borg-Warner.

Borg-Warner also began offering this spring a new acrylonitrile-butadiene-styrene (ABS) impact modifier for rigid PVC and a styrene-acrylonitrile (SAN) copolymer to improve flow characteristics for the same resin during processing. The ABS impact modifier especially aids low-temperature properties of PVC, the company says. The SAN material will contribute more fluid melt to PVC without reducing basic physical properties, and it doesn't affect clarity or contribute to haze in opaque and clear thermoplastic uses, according to the company.

As those examples indicate, most developmental work on plastics additives is done on the chemically reactive materials. By comparison, little work on fillers and reinforcements appears to be under way, despite their large-volume use. This year, of the 10 billion lb of additives going into plastics, about three quarters will be fillers and reinforcements. Few new materials for use in those applications have been found to have better performance than the ones now used, one industry source points out. Moreover, very few new fillers and reinforcements can compete cost-wise with currently used materials.

Fillers and reinforcements are used to some degree in all commercially significant resins. Loadings may vary widely, as they depend on the final makeup of the fabricated plastic product. Fabricated plastic products containing fillers and reinforcements typically use more than 20% by weight of these materials. These additives are over 90% by weight inorganic materials. Use of these materials relative to total resin consumption isn't expected to change much during the next few years, according to industry sources. Their consumption, however, will continue to grow with plastics consumption, with the rate of growth slightly lower than for all plastics.

Most fillers are used to provide bulk and lower the cost of the final product. Frequently, fillers provide other functions, such as increased weight, hardness, and chemical resistance. Some offer flame retardancy, thermal and electrical resistance, and appearance improvements. Carbon black, although accounting for only a small share of the total market for fillers, is widely used for its additional functional properties of UV light resistance,

Reductive Amination.

Creative catalysis coupled with a multipurpose hydrogenation facility.

Being experts in catalysis and process research means we can help find the most efficient route to the new specialty amines you need.

What's more, our facilities include modern research labs, a pilot plant and one of North America's largest batch hydrogenation plants. An expert team of scientists and commercial development specialists is dedicated to seeing that every project is handled in the most economically and technically effective way.

From R&D through scale up and commercialization, we can take your product from start to finish. This can cut your workload, capital investment and ease the demand on your research and manufacturing resources.

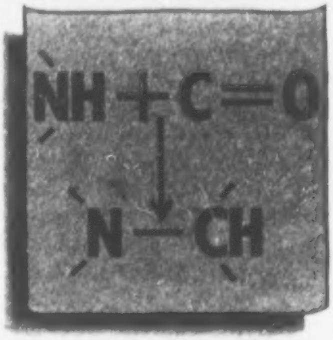
For specialty amines, and for all your carbon-nitrogen-based chemical needs, call us at 800-345-3148.

©Air Products and Chemicals, Inc., 1988

More than chemicals. Chemistry.

AIR PRODUCTS

CIRCLE 5 ON READER SERVICE CARD



insulation, and color. Calcium carbonate accounts for about half of filler consumption. Its share is forecast to decline slowly. However, it should remain the largest volume filler for a long time.

Glass fibers continue to dominate the reinforcements added to plastics, at about two thirds of the total. These fibers are available in several different forms, ranging from milled fibers to many kinds of fabrics. They account for about 15% of the total group of fillers and reinforcements added to plastics, and their share has been growing slowly, largely at the expense of asbestos.

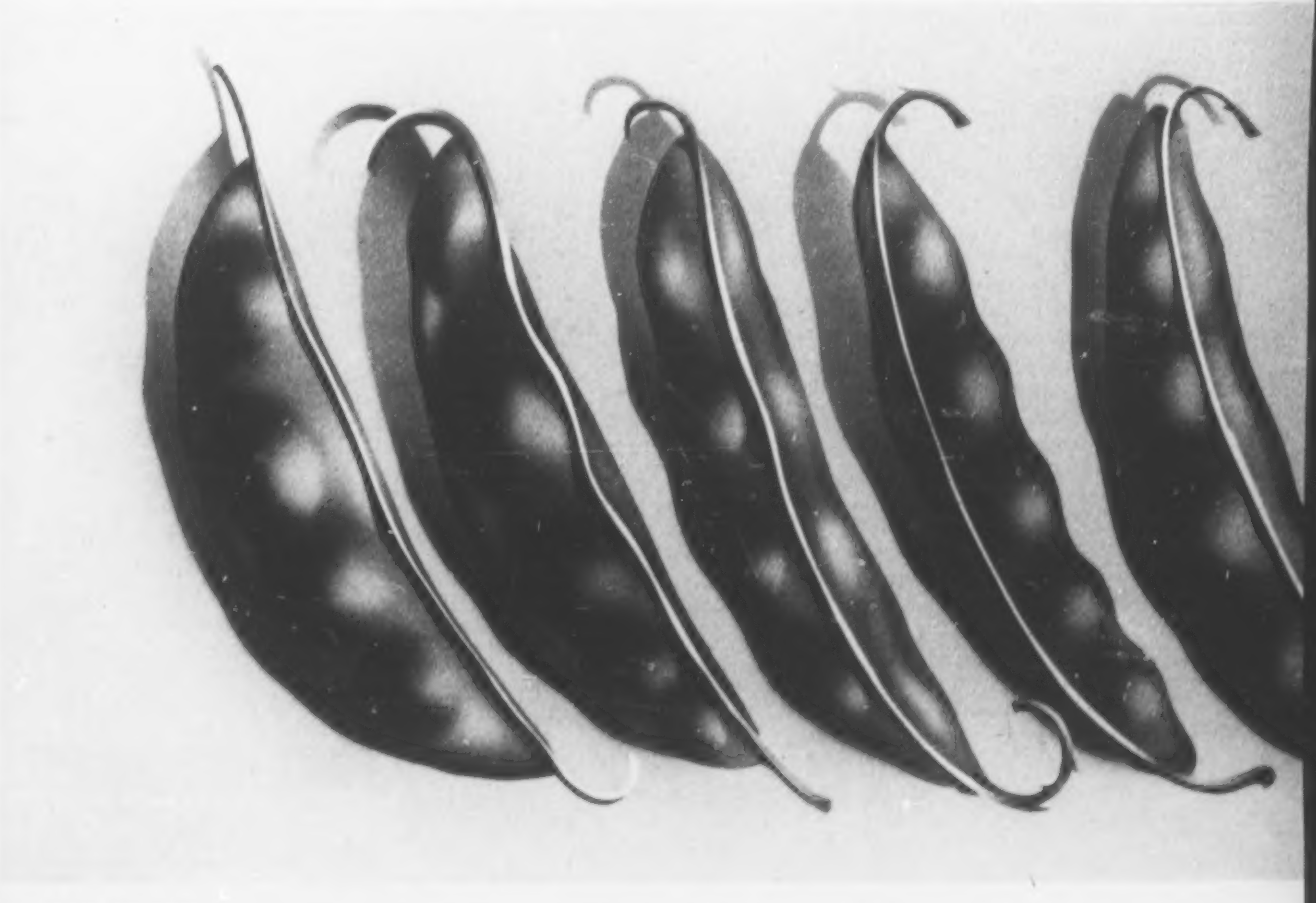
A few exotic organic fibers and carbon fibers compete with glass fibers as reinforcements in plastics. Until costs decline further or performance improves more to justify high costs, other fibrous reinforcement materials for plastics will barely challenge the position held by glass fibers.

Plasticizers rank next to fillers and reinforcements in the volume of materials consumed as additives. This year, plasticizer consumption could total more than 1.8 billion lb and exceed 2 billion lb in the early 1990s. Between 75 and 85% of plasticizer consumption is in PVC and copolymers of vinyl chloride. About half of the PVC produced contains a plasticizer. Other resins, such as polystyrene, acrylics, polyesters, polyvinyl acetate, and various thermosetting resins, sometimes utilize plasticizers in small quantities for certain end uses.

Growth in U.S. consumption of plasticizers likely will be below the average for all plastics additives or about 2.5% annually for the next few years. Part of the reason for slower growth stems from fewer new end uses being developed for vinyl plastic products that require plasticization. Another factor causing slower than average growth is the current rise in imports of fabricated vinyl plastic products.

Except for small amounts copolymerized into resins, plasticizers are compounded with finished resins and do not chemically react with the polymers. Generally, plasticizers are needed to give more flexibility to plastics. They lower the melt viscosity of the physical mixture as well as the glass transition temperature of resins. From a practical standpoint, plasticizers ease the subsequent processing of the mixture into finished products by such methods as extrusion, thermoforming, and molding.

The mechanism by which plasticizers work remains unclear. Among the possible mechanisms that have been suggested are the following: They act as a lubricant for macromolecules of resins, they reduce possible points of bonding between polymer chains, they continuously cause aggregation and deaggregation of various sized particles of resins through solvation, and they increase the free volume between resin mol-



ecules to give added flexibility. Probably a combination of these mechanisms occurs in most compounded plastics.

Most plasticizers used as plastics additives are various esters of organic acids or phosphoric acid, epoxidized soybean oil, and specialty polyesters. About two thirds of all plasticizers production in the U.S. is based on phthalic anhydride. Phthalate esters production in 1986, the latest year for which data are available, remained even with production in 1985 at 1.14 billion lb, according to the U.S. International Trade Commission. Principal alcohols combined with phthalic anhydride to make these plasticizers are 2-ethylhexyl, which gives dioctyl phthalate, and various linear alcohols in the C_6 to C_{12} range. Some higher alcohols, often with branched chains, also are used. Selection of the alcohol for the plasticizer can be a complex process, because a range of properties can be achieved in the final fabricated plastic product by varying the composition of the plasticizer.

Next in size to phthalate esters as plasticizers are the various epoxidized vegetable oils, of which soybean dominates. Epoxidized soybean oil plasticizers offer users relatively low cost, less migration from the plastic product, and some heat resistance, especially with some metallic derivatives added as heat stabilizers.

Several other chemicals are used as plasticizers for resins other than PVC. Besides the phosphate esters (use of these materials in plastics is small compared with other industrial uses), other commercially significant plasticizers are trimellitates, adipates, certain polyesters, and esters of many other organic acids, including citric, a specialty plasticizer for use in plastic packaging for foods.

Colorants is another large group of nonreactive plastic additives whose consumption may exceed 450 million lb in 1988, according to Freedonia Group estimates. As is the case with fillers, a large share of plastics output does not contain colorants. The number of colorants available from producers continues to grow, especially those with unusual effects such as fluorescence, phosphorescence, metallic character, and the luster and iridescent hues of pearlescence.

Despite continual work to develop new colorants, titanium dioxide and carbon black account for 80 to 90% of the colorants used in plastics. Consumption of titanium dioxide, because of its wide use in PVC pipe and fittings, siding, and other building products, is estimated to be more than three times larger than consumption of carbon black. (Use of carbon black in plastics is small compared with its use in elastomers.)

Colorant selection has been cited as one of the higher forms of the "black art" of plastics compounding.

The difference between our hydrazine and everyone else's.

More pure hydrazine hydrate. And fewer unwanted extras. That's what you get from ATOCHEM.

Impurities such as sodium chloride and heavy metals are virtually non-existent in our hydrazine. Which could lead to higher yields and fewer problems in your process.

Our patented production method makes the purity of our hydrazine unique. The difference: We use peroxide compounds where others use sodium hypochlorite. And since we don't start with sodium, we don't end up with related by-products.

We don't give you lots of impurities in our hydrazine, but we do give you more of what you're looking for in a supplier.

Like technical service—no one knows hydrazine better than we do. And fast delivery—we'll ship within 24 hours from one of our six warehouses throughout the U.S., in a range of packaging options from small drums to bulk shipments.

Stop paying for what you don't want. Specify ultra-pure hydrazine from ATOCHEM.

Contact Olivier Meurzec,
Marketing Mgr., ATOCHEM INC.,
Chemical Division, P.O. Box 607,
Glen Rock, NJ 07452.

For Immediate help,
call us Toll Free at
1-800-932-0420.
In NJ: (201) 652-8575.

ATOCHEM INC.
elf aquitaine group ATO

CIRCLE 38 ON READER SERVICE CARD

Put Our Heads On Your Foam Problem.

The antifoam experts at Dow Corning will find the answers.

And recommend the right antifoam agent from our broad line. Whether your problem is with high or low pH. Or with high temperature. Or for food-related uses. For both aqueous and non-aqueous systems.

Remember, our antifoams are concentrated to go a long way, and last a long time.

For samples or answers from the antifoam experts…

Call 1-800 FOAM FREE

Or write: Dow Corning Corporation,
Dept. A-7016, P.O. Box 7604,
Mt. Prospect, IL 60056-7604.

DOW CORNING®

©1988 Dow Corning Corporation

CIRCLE 12 ON READER SERVICE CARD

Many suppliers offer big volume and specialty plastics additives

Antioxidants
- American Cyanamid
- Borg-Warner
- Ciba-Geigy
- Ethyl
- Ferro
- Hoechst Celanese
- ICI Americas
- Mobay
- Monsanto
- Olin
- Sandoz
- Uniroyal
- Witco

Antistatic agents[a]
- Akzo
- American Cyanamid
- Ferro
- Harwick Chemical
- Henkel
- Hoechst Celanese
- ICI Americas
- Lonza
- Mobay
- Sherex
- Witco

Blowing agents
- Ampacet
- Henley Chemicals
- Hoechst Celanese
- Mobay
- Olin
- Pennwalt
- Sherex
- Uniroyal
- Witco

Catalysts
- Air Products
- Akzo
- American Cyanamid
- BASF
- Ciba-Geigy
- Dow Chemical
- Du Pont
- Ethyl
- Olin
- Pennwalt
- PPG Industries
- Texaco Chemical
- Witco

Colorants[b]
- American Cyanamid
- BASF
- Borden Chemical
- Ciba-Geigy
- Du Pont
- Ferro
- Hoechst Celanese
- ICI Americas
- Mobay
- Sandoz
- Sun Chemical
- Witco

Coupling agents
- Degussa
- Dow Corning
- Du Pont
- Dynamit Nobel
- PCR Inc.
- Union Carbide
- Witco

Crosslinking agents
- Akzo
- American Cyanamid
- BASF
- Ciba-Geigy
- Diamond Shamrock Chemicals
- Dow Corning
- Du Pont
- GAF Chemicals
- PCR Inc.
- Pennwalt
- PPG Industries
- Reichhold Chemicals
- Union Carbide
- Witco

Emulsifiers
- Akzo
- Ashland Chemical
- BASF
- Ciba-Geigy
- Diamond Shamrock Chemicals
- Dow Chemical
- Du Pont
- Eastman Kodak
- C. P. Hall
- Hoechst Celanese
- ICI Americas
- Rohm & Haas
- Union Carbide
- Witco

Fillers
- Akzo
- Aluminum Co. of America
- Amspec Chemical
- Ashland Chemical
- Cyprus Industrial Minerals
- E. C. C. America
- Freeport Koalin
- Great Lakes Mineral
- J. M. Huber
- Milwhite
- Mobay
- PPG Industries
- PQ Corp.

Flame retardants
- Aluminum Co. of America
- Ampacet
- BASF
- Dow Chemical
- Ethyl
- Ferro
- Hoechst Celanese
- M & T Chemicals
- Monsanto
- Occidential Chemica
- Olin
- PPG Industries
- Solem Industries
- Uniroyal
- Witco

Heat stabilizers
- Akzo
- American Cyanamid

The organic colorants, other than carbon black, are the most difficult to use, because heat, other additives, and their own physical properties can cause partial or complete loss of color during processing and subsequent possible migration to surfaces. Color concentrates, frequently containing various other plastic additives as well, are used most often in compounding.

Growth of flame retardants as plastics additives has slowed, according to recent estimates by Freedonia Group, but is forecast to increase to above the average growth rate for all additives. Flame retardant demand will exceed 525 million lb in 1988 and likely will near 1 billion lb by the year 2000.

Flame retardants may be used in most, but not all, resins. They are used to chemically and/or physically limit the combustion process by several different mechanisms. In addition, they may provide some degree of smoke suppression. The amount of inert materials used in a compounded plastic product greatly affects combustion, as do other additives that have flame retardancy as a secondary function (for example, the phosphate esters whose major function is plasticization).

Inorganic compounds, largely aluminum hydrates and metal oxides, account for more than half of the consumption of flame retardants. The next largest group is a wide variety of halogenated organic com-

Ampacet
Borg Warner
Ciba-Geigy
Eagle Picher
Ferro
M & T Chemicals
Mobay
Morton Thiokol
Olin
Union Carbide
R. T. Vanderbilt
Witco

Impact modifiers
Amoco
Borg-Warner
Firestone
B. F. Goodrich
Harwick Chemical
M & T Chemicals
Mobay
Rohm & Haas
Shell Chemical
Union Carbide
Uniroyal
Witco

Lubricants
Akzo
Borg-Warner
Dow Corning
Eastman Kodak
General Electric
C. P. Hall
Hoechst Celanese
Lonza
Morton Thiokol
Shell Chemical

Sherex
Union Carbide
Witco

Plasticizers
Akzo
BASF
Dow Chemical
Du Pont
Eastman Kodak
Exxon Chemical
Ferro
C. P. Hall
ICI Americas
Mobay
Monsanto
Olin
Shell Chemical
Uniroyal
Witco

UV stabilizers
American Cyanamid
Asarco
BASF
Ciba-Geigy
Du Pont
Eastman Kodak
Ferro
Hoechst Celanese
ICI Americas
NL Chemicals
Sandoz
Witco

Note: Representative listing of producers of some functional plastic additives. a Internal and external. b Basic only

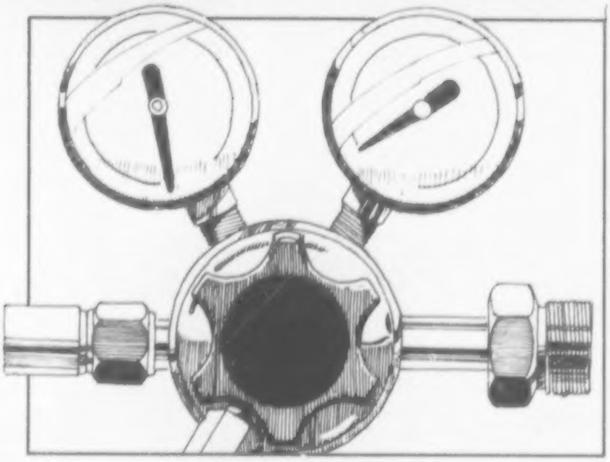
pounds. Phosphate esters, some of which are halogenated, probably are the third largest group.

Aluminum trihydrate, also used as a filler in plastics, continues to find large-volume use because of its low cost. It can be heated to decompose to the oxide, which acts as a partial heat sink, and water vapor, which dilutes the concentration of flammable materials and oxygen and also takes up heat. Much of the consumption of aluminum trihydrate is in thermoset plastic items.

Halogenated hydrocarbons, both brominated aliphatic and aromatic derivatives, find most use in polyolefins and polystyrenes. Frequently, a synergist, such as antimony oxide, iron oxides, or zinc borate,

SEE US AT NPE BOOTH #1232

New Design Opportunities



Now you can replace traditional materials with Vectra® LCP.

Vectra® liquid crystal polymers exceed all other thermoplastics in performance, tolerance and processing ease. This remarkable new plastic family has proven itself in the electrical, automotive, electronic components and telecommunications markets and we are already developing significant new potential in pumping and fluid handling applications.

Vectra is the result of over ten years of intensive product development. With truly superior mechanical, thermal and electrical properties, Vectra resins can replace metals, ceramics and thermosets, giving you an unsurpassed array of cost-effective benefits:

- Exceptional dimensional stability over broad temperature range
- Excellent toughness and impact resistance with maximum strength
- High temperature performance up to 575° F
- Outstanding chemical resistance
- Virtually zero mold shrinkage for precision tolerances
- Withstands repeated sterilization: steam, gas and gamma to 500 Mrads
- Low wear characteristics and low warpage
- Fast cycles/regrind utilization

Engineering Plastics Division
Hoechst Celanese Corporation

Hoechst Celanese Hoechst

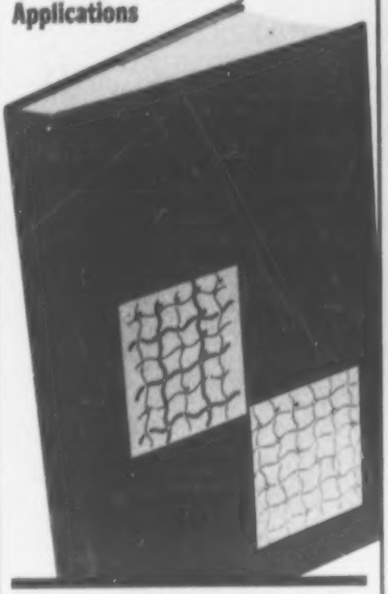
Call 1-800 235-2637

® is a registered trademark of Hoechst Celanese Corporation.
® The Hoechst name and logo are registered trademarks of Hoechst AG.
© 1988 Hoechst Celanese Corporation.

CIRCLE 16 ON READER SERVICE CARD

Cross-Linked Polymers

Chemistry, Properties, and Applications



Cross-Linked polymers are used in a wide variety of aerospace, automotive, building construction, and consumer product applications. This new book presents the latest research results on cross-linked polymers from internationally recognized scientists. You'll learn why cross-linked polymers are superior in applications requiring resistance to high temperatures and high mechanical performance. You'll cover current topics in network theory, along with an explanation of the relationship between molecular architecture and macroscopic physical properties. You'll read about all the main points of cross-linked polymer systems, including:

- **Network Modeling and Structure**
- **Network Formation and Degradation**
- **Network Characterization**

Cross-Linked Polymers will prove a valuable resource to all polymer scientists and engineers working with cross-linked polymers in coatings, aerospace, adhesives, electronics, and automotive applications.

Ray A. Dickie and S.S. Labana, *Editors, Ford Motor Company*

Ronald S. Bauer, *Editor, Shell Development Company*

Developed from a symposium sponsored by the Division of Polymeric Materials: Science and Engineering of the American Chemical Society

ACS Symposium Series No. 367
576 pages (1988) Clothbound
ISBN 0-8412-1471-9 LC 88-3327
US & Canada **$99.95** Export **$119.95**

Order from: American Chemical Society
Distribution Office Dept. 85
1155 Sixteenth St., N.W.
Washington, DC 20036

or CALL TOLL FREE

800-227-5558

and use your credit card!

Photo by Uta Von Nurenburg

Additives facilitate molding of plastic amusement park cars

will be included as part of the additive package.

Some of the halogenated hydrocarbon flame retardants, as well as some phosphorus derivatives, can be reacted with resin monomers and be made part of the polymer and distinguished as reactive flame retardants. Probably the most important use of reactive flame retardants is in epoxy resins that eventually become part of electronic components.

Phosphate esters are used as flame retardants in PVC, polyurethanes, and various engineering resins. Some are used predominately in urethanes. Phosphate esters also find significant use as plasticizers. Antimony oxide has been a strong competitor to the phosphate esters in many applications, limiting growth of the esters to well below the average growth of all flame retardants.

Impact modifiers are used largely in PVC to greatly increase resistance to stress fracturing of this resin's compounded and fabricated forms, particularly bottles, film, and sheet. Most impact modifiers are ABS or methacrylate-butadiene-styrene (MBS) polymers. Next in importance are the acrylic and modified acrylic polymers. Many other materials also are used as impact modifiers, including chlorinated polyethylene, ethylene-vinyl acetate, and various elastomers such as polybutadiene, ethylene-propylene-diene, and styrene-butadiene rubbers and fluoroelastomers.

The impact modifier used depends on the expected final use of the plastic part. In general, MBS is used more in products in which clarity is important, such as bottles for liquid consumer products. If the product is to be opaque, such as injection molded or sheet products, then the modifier is more likely to be ABS. For best resistance to weather—for example, vinyl siding—an acrylic polymer is favored.

Consumption of impact modifiers for plastic products has been rising faster than consumption of all additives. This year, about 140 million lb of these elastomeric-type materials will go into plastics, with use rising to 200 million lb by 2000, forecasts Freedonia Group. Growth in use of impact modifiers is expected to continue because of the increased market for PVC bottles, credit cards, automobiles, and siding.

Lubricants as plastics additives may encompass more different compounds and proprietary products than any other functional additive class except colorants. As a result, lubricants are used in a large number of the commercially available resins. Many of the chemicals considered lubricants can have other functions when incorporated into resins. Compounding with lubricants frequently can be unpredictable, according to industry sources, because of the often multifunctional characteristics of many materials used primarily as lubricants and because of their interaction with other additives going into plastics. About 100 million lb of lubricants are expected to be used in plastics this year, with growth lagging that of all additives.

Metallic soaps, mostly stearates, are the largest volume lubricant used. Combinations of these soaps can have a synergistic effect as lubricants. But besides their lubricating properties, those compounds act as mold release agents, heat stabilizers, and antiblocking agents. Use varies, depending on the metal.

Fatty acid amides rank next to metallic soaps in volume of use. These compounds provide two hydrocarbon chains linked at a polar group. As a result, they, too, have multifunctional properties, such as antiblocking and antistatic, as well as promoting flow and release of the compound from metal-forming devices.

Other materials used in significant volume as lubricants and for other functions are fatty acids and esters, fatty alcohols, paraffin and polyethylene waxes, silicones, fluoropolymers, and inorganic compounds. There is no completely reliable method for selecting the best lubricant from the long list of possible materials. Analytical methods are widely employed to attempt to predict the optimum lubricant, but the expertise of plastics compounders is required to balance the functions of lubricants and other additives if a lubricant is to be used in the processing of resins into products.

The majority of heat stabilizers used as plastics additives go into PVC and related resins. Generally, the purpose of these stabilizers is to react with hydrogen chloride released at points in PVC chains where branching or crosslinking occurs. About 85 million lb of various heat stabilizers will be consumed this year, slightly below the average annual consumption during the past 10 years. The slow decline in consumption of heat stabilizers in PVC stems from improvements in PVC performance and a decline in fabrication of PVC in the U.S. resulting from rising imports of consumer nondurables made of PVC.

Organometallic salts account for about 40 to 50% of the consumption of heat stabilizers. The metals include barium, cadmium, calcium, zinc, potassium, and tin; the organic portion includes fatty acids, substituted phenols, and dialkyl carboxylates. Other chemicals may be combined with these compounds to act as synergists. These additives also have various secondary functions and can affect solubility of plasticizers, lubricity, and clarity.

Organotin compounds are considered to be the premium heat stabilizers because they perform well in applications where clarity and weatherability properties are important. Their cost is high, however. Various organic and inorganic lead compounds are used as heat stabilizers in PVC, largely in wire and cable insulation.

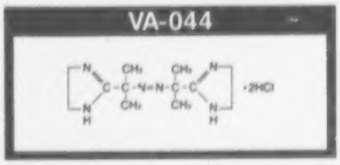
Although the need for UV stabilizers in plastics is supposedly high, consumption of these additives amounts to only about a tenth of the consumption of heat stabilizers. The relatively small volume of UV stabilizer consumption—probably about 8 million lb this year—is partly due to adequate performance of these materials at low concentrations. Limited volume of use also results from use of colorants and fillers, which provide some degree of UV protection. A third factor, and for many plastic products a critical one, is the high cost of UV stabilizers, most of which are complex organic molecules that are expensive to synthesize.

UV stabilizers operate by absorbing UV light, decomposing the peroxides that form by action of UV light, scavenging radicals that form from action of UV light (a process similar to that of antioxidation), or quenching of excited states caused by UV light. A newer class of UV stabilizers is a group of compounds known as hindered amine light stabilizers (HALS). Other classes include the benzophenones, benzotriazoles, nickelorganics, and various pigments.

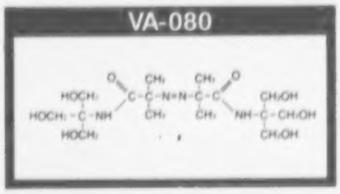
Well over half of UV stabilizer consumption is in polyolefins. Fre-

Polymerization initiators

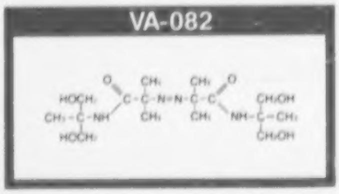
VA-044



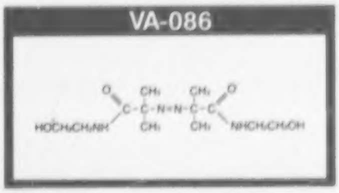
VA-080



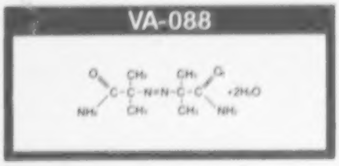
VA-082



VA-086



VA-088



Fore more information call or write:

Wako

Wako Pure Chemical Industries, Ltd.
10 Doshomachi 3-Chome, Higashi-Ku,
Osaka 541, Japan
Telephone: (06) 203-3741
Telex: 65188 wakoos j
Facsimile: (06) 222-1203

Wako Chemicals USA, Inc.
12300 Ford Road, Suite 130,
Dallas, Texas 75234, U.S.A.
Telephone: (214) 484-7518
Telex: 293208 wako ur
Facsimile: (214) 484-7243

Wako Chemicals GmbH
Nissanstr. 2, 4040 Neuss 1,
West Germany
Telephone: (02101) 35011
Telex: 8517001 wako d
Facsimile: (02101) 39879

CIRCLE 46 ON READER SERVICE CARD

INTENTIONAL
BLANK

quently, if UV stabilizers are used, combinations of a HALS and a benzophenone or a benzotriazole will be added to a polyolefin-molded item to gain synergism. Rubber-modified polystyrenes also especially benefit from use of combinations of UV stabilizers. Other resins in which UV stabilizers frequently are used include PVC, urethanes, polycarbonates, and unsaturated polyesters.

Growth in the use of antioxidants in plastics exceeds the growth of all additives, but the rate has been slowing. This year, about 45 million lb of various antioxidants will go into plastics, with consumption reaching 50 million lb in 1992, for an annual average growth rate of 3.5%, according to Freedonia Group. Although antioxidants go into most resins, their largest use is in polyolefins and polystyrenes.

Plastics in autos spurs market for additives, particularly impact modifiers

Most antioxidants used in plastics are classified as either primary or secondary. Primary antioxidants, such as hindered phenols and secondary amines, scavenge free radicals. The secondary antioxidants—for example, phosphites and thioesters—decompose peroxides. Butylated hydroxytoluene (BHT) probably remains the most important of the hindered phenol antioxidants. However, its use has declined because of the difficulty in using it in linear low-density polyethylene, one of the faster-growing polyolefins. Even so, BHT and other hindered phenols account for about 40% of consumption.

Secondary amines have fallen into disfavor because they tend to stain plastic products. If discoloration is not a concern or is covered by colorants, these amines can be used for other functions as well as hindering oxidation.

Use of various phosphites has been growing rapidly because they work better with the HALS UV stabilizers than do the thioesters. Phosphites also have other functions as additives; they can inhibit melt index changes during processing and provide additional processing stability.

Many other kinds of plastics additives are offered, some for specific uses in certain resins and some for limited use in many different resins. Aggregate demand for all of these other additives totaled about 185 million lb in 1987, estimates Freedonia Group. The largest in consumption of these additives is the organic peroxides, followed by chemical blowing agents, antimicrobial agents, and antistatic agents.

The peroxides decompose during their action and hence may not strictly be called additives, although their by-products remain. They are used mostly to cure unsaturated polyesters, to crosslink polyethylenes used as wire and cable coverings, and as initiators for polyolefins,

Thermoplastic Processing Aids

Meeting the needs of today's new alloys

- **Anti Static Agents**
- **High Temperature Slip Additives**
- **Anti-Oxidants**
- **Phase Transfer Catalysts**

Write or call for more information.

HEXCEL chemical products

Chemical Products Div., 215 N. Centennial St., Zeeland, MI 49464 (616) 772-2193 Telex 226 375

CIRCLE 15 ON READER SERVICE CARD

PVC, polystyrene, and acrylates. A large number of different peroxides such as alkyl, aryl, and diacetyl peroxides, and peroxyesters are offered. Growth in demand for the entire group of organic peroxides used as additives trails that of all additives. Some peroxides, such as the peroxyesters, have a relatively high growth because of demand for a particular resin. But the overall growth of peroxides is offset because some will no longer be offered commercially.

Most of the blowing agents used are physical rather than chemical agents. Most physical blowing agents (90% or more of the total) are gases or volatile liquids that produce foamed plastics when pressure is reduced. The chemical blowing agents are largely hydrazine derivatives, of which azobisformamide is the most important. The materials yield nitrogen and other gases and leave various residues. Most chemical blowing agents are used in PVC and crosslinked polyethylene. About 13 million lb of chemical blowing agents are forecast to be consumed this year.

Relatively few biocides are used as plastics additives because most cannot survive the temperatures often encountered during processing. Also the cost of government registration is a factor. Those that are used go mostly into PVC and polyurethanes, with lesser amounts going into polyolefins. This year, more than 10 million lb of biocides will go into plastics, mostly as concentrates in plasticizers or solvents. Examples include organometallic compounds and nitrogen-sulfur heterocyclics, which are fungicides similar to those used in agriculture.

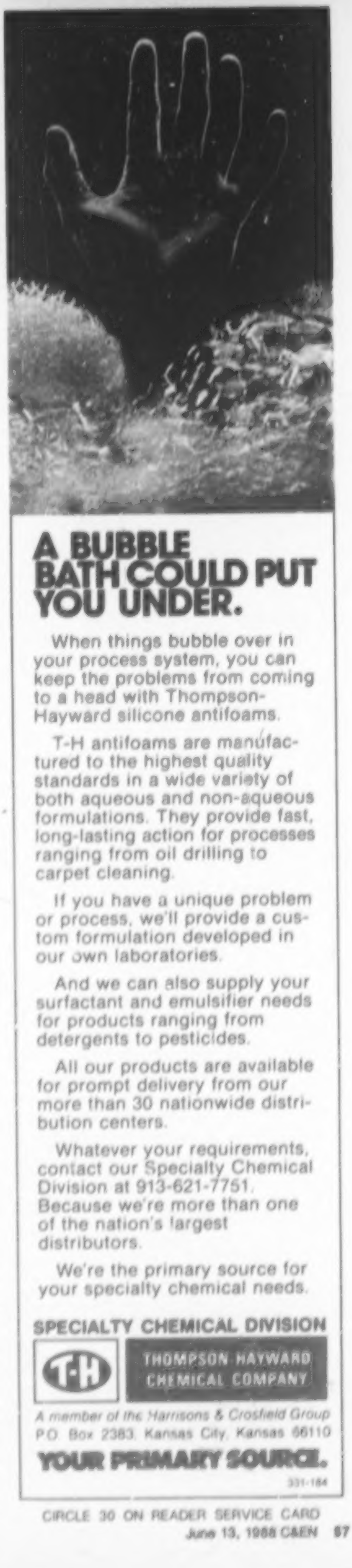
Use of antistatic agents this year will be less than 10 million lb, and growth exceeds that of all additives. Antistats are classified as either external or internal. External materials are used as coatings and, in a major use, are aimed at ensuring the pleasing appearance of bottles containing cosmetic, edible oils, and cleansers, by preventing deposition of dust during shipping and shelf storage. Examples of external antistats are quaternary ammonium compounds and derivatives and various ethoxylated and propoxylated aliphatics and aromatics.

Internal antistats, often supplied in an additive package containing other materials as well, are compounded into PVC, polyolefins, and polystyrene at relatively low concentrations. Those antistats move to the surface (called blooming) of the fabricated plastic item to provide a continuing function in contrast to external antistats that may be easily washed off. Ethoxylated amines are the major-volume internal antistats, and go mainly into polyolefins.

Numerous additives with special functions are available to processors. Freedonia Group estimates that demand for these additives, which include coupling agents, emulsifiers, mold release agents, slip and antiblocking agents, and viscosity depressants, will amount to about 110 million lb this year, of which 6 million lb will be catalysts for urethanes. Frequently, special functions are secondary activities of additives having more than one function.

Coupling agents act to modify surfaces of chemically inert additives such as fillers and reinforcements to help bond them to resins. Most coupling agents are silanes and titanates. Many kinds of emulsifiers are used, both in polymerization of monomers and in processing resins; other additives also may partially provide this function. Fragrances, usually added in concentrates, mask odors of plastics and other additives or provide pleasant odors for garbage bags and air fresheners. Mold release agents range from simple waxes to complex fluoroelastomers and are designed to not combine with plastics. Slip and antiblocking agents perform similar functions to mold release agents except that they are used mostly with film and with sheet forming. Viscosity depressants frequently are used in PVC plastisols as an effective substitute for plasticizers.

The current diverse and complex use of plastics additives augurs well for the continuing development of these materials in the future. Despite reduced consumption of additives per unit weight of plastic resins, the increasing number of new products being brought to market each year clearly indicates that suppliers are bullish on the outlook for plastics additives. □


A BUBBLE BATH COULD PUT YOU UNDER.

When things bubble over in your process system, you can keep the problems from coming to a head with Thompson-Hayward silicone antifoams.

T-H antifoams are manufactured to the highest quality standards in a wide variety of both aqueous and non-aqueous formulations. They provide fast, long-lasting action for processes ranging from oil drilling to carpet cleaning.

If you have a unique problem or process, we'll provide a custom formulation developed in our own laboratories.

And we can also supply your surfactant and emulsifier needs for products ranging from detergents to pesticides.

All our products are available for prompt delivery from our more than 30 nationwide distribution centers.

Whatever your requirements, contact our Specialty Chemical Division at 913-621-7751. Because we're more than one of the nation's largest distributors.

We're the primary source for your specialty chemical needs.

SPECIALTY CHEMICAL DIVISION

T-H THOMPSON HAYWARD CHEMICAL COMPANY

A member of the Harrisons & Crosfield Group
P.O. Box 2383, Kansas City, Kansas 66110

YOUR PRIMARY SOURCE.

331-184

CIRCLE 30 ON READER SERVICE CARD

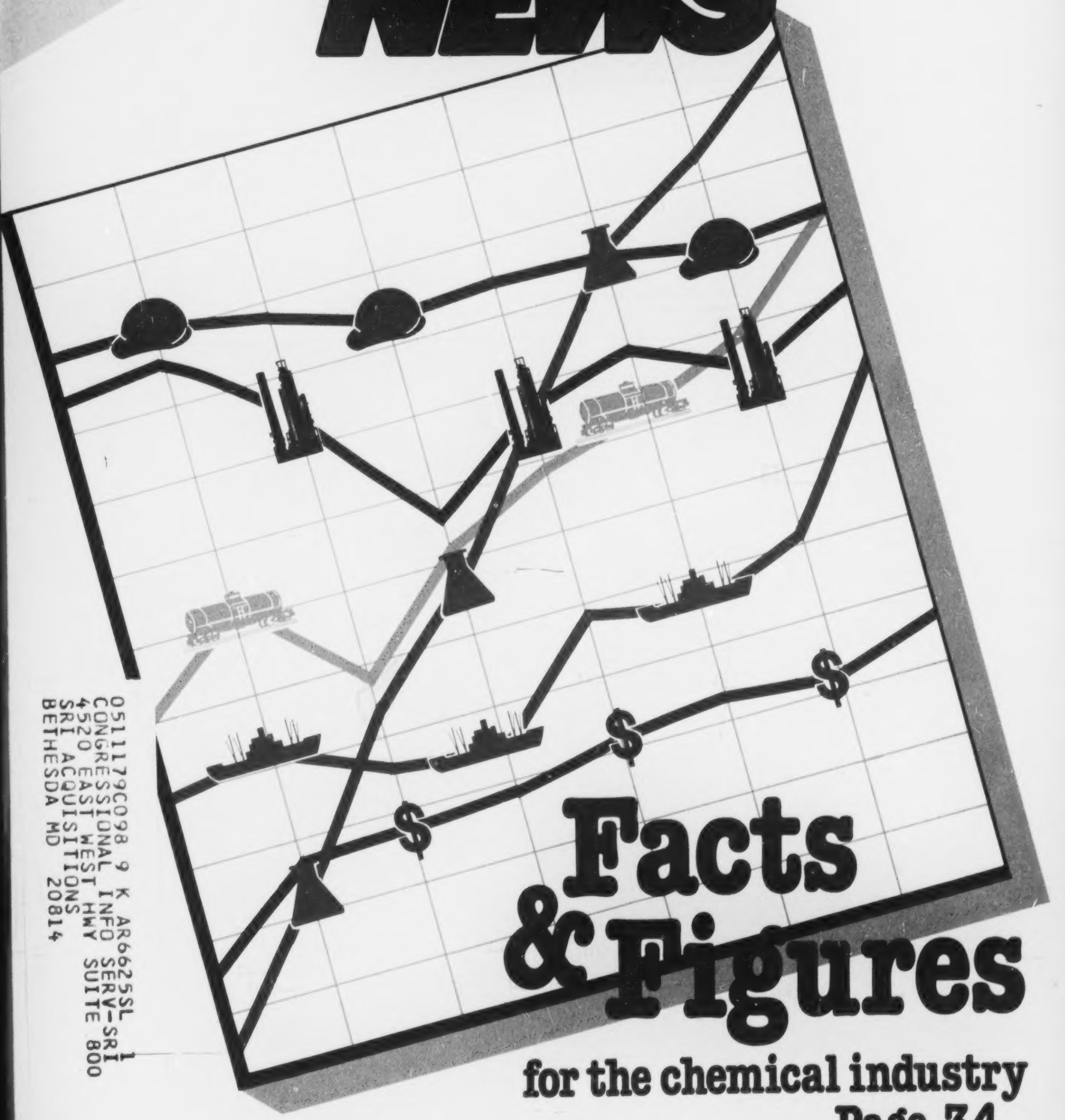
6/22/88

A1250-1

Scientific news from the chemical congress in Toronto

JUNE 20, 1988

CHEMICAL & ENGINEERING NEWS



Facts & Figures

for the chemical industry

Page 34

0511179C098 9 K AR6625SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 25
CENEAR 66 (25) 1–96
ISSN 0009-2347

JUNE 20, 1988

News of the Week

- **In more than 3000 papers presented at AIDS conference in Stockholm last week, new findings were reported, but no breakthrough was announced.** Page 4
- **New initiatives to address chemical safety problems and negative perceptions of chemical industry were announced at recent CMA annual meeting.** Page 5
- **Last week's public hearing on NIH's intramural research program focused on the difficulties in recruiting and retaining high-quality research personnel.** Page 5
- **NIH researchers seek approval to conduct a medical experiment that would introduce genetically engineered cells into human beings.** Page 6
- **Signing of U.S.-Soviet agreement for cooperation in basic scientific research at Moscow summit was prevented by objections from U.S. agencies.** Page 6

Business

Grace Specialty Chemicals, a cornerstone of W. R. Grace & Co., stresses service as ingredient for success. **Page 9**

Government

Industries pressured by July 1 deadline for filing toxic release data required by right-to-know act; foreign competitiveness aired in Senate hearings; extensive environmental agenda being compiled for next President and his Administration. **Page 13**

Science

From the Toronto meeting: studies of enzyme activity in nonaqueous media lead to better understanding of enzyme function; research on gas-phase clusters provides insight into atmospheric chemistry. **Page 21**

Technology

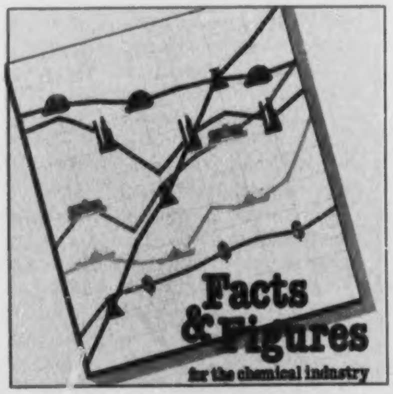
More from Toronto meeting: structure of zeolite beta determined using combination of direct measurements and computer modeling; catalytic technique developed for coprocessing of coal, petroleum; functionalizing carbon molecular sieves with catalytic species. **Page 23**

Education

The Toronto meeting continued: three innovative Canadian chemistry professors aid public understanding of chemistry. **Page 29**

ACS News

Chemical Congress in Toronto offered participants a variety of activities, captured on film by C&EN's roving photographer. **Page 83**



Facts & Figures

Production of chemicals continued to expand last year, and the U.S. chemical industry had what was probably its best year of the past decade in terms of sales and profitability. C&EN's annual statistical wrapup presents data on the industry's performance in the U.S. and abroad. Page 34

Letters 2
Concentrates
Business 7
Government 12
Science/Technology 20
The Departments
Meeting Briefs 32
Newscripts 96

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 95)

LETTERS

CHEMICAL SAFETY

Barium acetate pyrolysis

SIR: Concerning the explosion reported by Niles Fleischer (C&EN, April 11, page 4), I would like to point out that the pyrolysis of barium acetate gives acetone in high yield. Furthermore, on the basis of unpublished experiments I performed many years ago, I would surmise the decomposition of the acetate is being catalyzed by the added metallic oxides.

Jose Castrillon
Head, Department of Chemistry
Pan American University

Environment and technology

SIR: As a scientist who has worked with environmental groups, I dispute Fred Tausch Jr. (C&EN, April 18, page 2) who depicts a negative sum game between environmentalism (based on disparaged social science) and technology (based on physical science). Nothing could be further from the truth.

Absent the "softer" sciences, there would be no defined property rights or market exchanges—without which there would be little of the innovation in manufacturing and services that mark the real and growing differences between free market economies and those that are centrally controlled. (Nor would we enjoy the right to comment on such matters in letters to editors.) A more thoughtful inspection of law and economics offers the effective solutions sought by both Tausch and his erstwhile tormentors.

Many efforts to improve environmental outcomes have relied upon rigid, central mandates—minimum standards, best available control technologies, and fixed timetables. User fees, tradable entitlements, and other market-oriented approaches have been ignored even though nearly all technologists and economists support them. Yet environmental dilemmas are characterized by ill- or undefined property rights to resources or to institutional barriers to the exchange of such rights. Why have we ignored market solutions?

Some reasons: Market-directed environmental incentives are opposed by those whose interests are aligned with the status quo; these include polluters and bureaucrats as well as some environmental enthusiasts. (If your lawyers are experienced with the present, hopelessly inefficient approach, it is risky to adopt a new system, especially if the present regimen appears to lend you a comparative advantage.) Many decision makers don't understand or don't believe microeconomic theory. And, as public choice economists conclude, free market institutions reduce the power of bureaucrats and legislators to grant favors to friends or buy votes, thereby devaluing their political capital.

Tausch suggests that all environmental groups are hostile to technology, that they seek a regimen of "selective draconian enforcement" and that they ignore or even welcome the "extortion, fraud, incompetence, and corruption" that necessarily follow. The environmental groups I know best would confound him. These include the Environmental Defense Fund (EDF), the Foundation for Research on Economics & the Environment, and the Political Economy Research Center, based in New York, Dallas, and Bozeman, Mont., respectively.

Ironically, people like Tausch are superb environmental fund raisers if they attain high office; Interior Secretary James Watt was a good example. Efforts to play positive sum games in ameliorating environmental problems are not as newsworthy—or as easily funded—as actions that engender vituperative attacks on industry or environmental groups. How exciting is it when the Nature Conservancy uncovers tax incentives to purchase wildlife habitat or EDF shows how farmers and cities might trade conserved irrigation water?

As for litigation, most C&EN readers don't know that environmentalists spent many years and million of dollars intervening to implement time-of-day power rates. Working with (yes, with!) the chemical industry's Petrochemical Energy Groups, EDF put a stop to uneconomic synthetic gas plants a decade ago. Such steps didn't just benefit the environment, they saved tens of billions of energy consumers' dollars (including industrial users') and improved the finances of dozens of gas and electric utilities. Yet these and other actions that predicated environmental reforms on sound economics have received no publicity because they lacked conflict and rancor or because the real villain turned out to be outdated government regulation.

To identify such positive sum environmental games, we must understand how institutional arrangements govern incentives. C&EN covers this territory and, with little added effort, it could play a role in uncovering opportunities. Better yet, imagine their joint credibility

Facts &

for the chemical industry

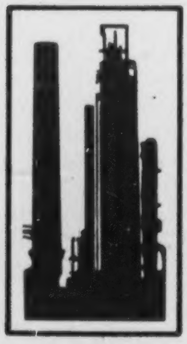
Chemical production increased in the U.S. last year, marking the fifth straight year of growth for the industry. Practically all major segments of the industry benefited from increased demand, although it was plastics that, as usual, set the pace. And as a consequence, many producers of plastics and of the feedstocks used to make them were running their plants at or near capacity.

With customers clamoring for more products, chemical companies basked, too, in the unusual ability to raise selling prices as well as output. Sales volume climbed, but profits surged even higher. All in all, 1987 was an untypically pleasant year to be in the chemical business.

Evidence of this radiates from the tables and graphs spread across the following pages of C&EN's annual Facts & Figures issue. Here are presented the statistical details that provide a measure of the chemical industry's performance during the past few years, both in the U.S. and to a lesser extent elsewhere among the world's other leading chemical-producing nations. The data come from a diverse array of sources, including government agencies, trade associations, international organizations, and the companies themselves that make up the industry. In many cases, these data have been treated analytically to add perspective to the trends taking place recently in the complex chemical industry.

at a glance

1. Production



The U.S. chemical industry raised its output last year nearly 6% overall. Plastics kept their typical hold on the head of the growth ranking, and in doing so bolstered the production of the many organic chemicals from which they are concocted. But organic intermediates also got a boost from strong growth for synthetic fibers. Meanwhile, a recovery for fertilizers led to higher production for several big-volume inorganic chemicals, such as sulfuric, nitric, and phosphoric acids. Page 37

2. Finances

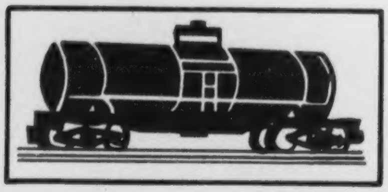
Income statements issued by the chemical industry at the end of 1987 haven't looked better in several years. The favorable combination of increased plant output and higher selling prices shoved sales upward and, coupled with the cost-cutting programs of previous years, gave a stout boost to companies' profitability. For a sampling of 30 major chemical companies, profit margins had not been so high in more than a decade. With demand strong, the industry has been cautiously raising its capital spending budgets, both at home and abroad, and plowing more money into R&D. Page 45

Figures

3. Employment

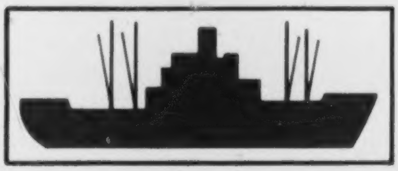
After declining for more than two years, employment in the chemical industry was on the increase during the second half of 1987. For the year as a whole, however, the number of workers in the industry averaged less than 1% more than during the previous year—and remains well below the level of the early 1980s. Because production was up, however, labor productivity improved further, although as wage rates increased unit labor costs were little changed from 1986. **Page 63**

4. Markets



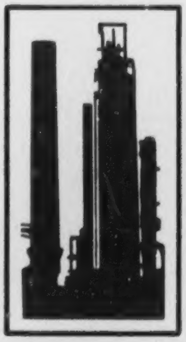
The further expansion of the overall U.S. economy and of consumer spending has stimulated a steadily rising demand for chemical products during the past five years. Two major markets that were less buoyant last year were home construction and auto production. But customers in such diverse industries as textiles, paper, home appliances, furniture, and plastics products more than made up the slack. **Page 66**

5. Foreign Trade



The U.S. balance of foreign trade in chemicals improved significantly last year as exports rose 16% but imports climbed only about half as much. Weakness of the dollar is largely responsible, as chemicals produced in the U.S. became less expensive in foreign markets but chemicals manufactured overseas were put at a price disadvantage in the U.S. **Page 68**

6. Foreign Chemical Industries



The favorable business climate enjoyed by U.S. chemical producers was matched in major chemical-producing nations elsewhere. In Europe, chemical output was moderately higher, but most large chemical companies were the beneficiaries of overall prosperity. Japanese chemical firms likewise benefited from strong domestic sales and made a good recovery in profitability from the relatively weak previous year. Sales and profits also improved in Canada. **Page 73**

Expansion persists through five years

Production by the U.S. chemical industry continued to grow moderately in 1987, rising 6% over 1986. That's the best year-to-year growth since 1983 and 1984, when the industry was recovering from the recession of the early 1980s. The increase for chemicals was slightly better than that for industry as a whole, which was up only 4%.

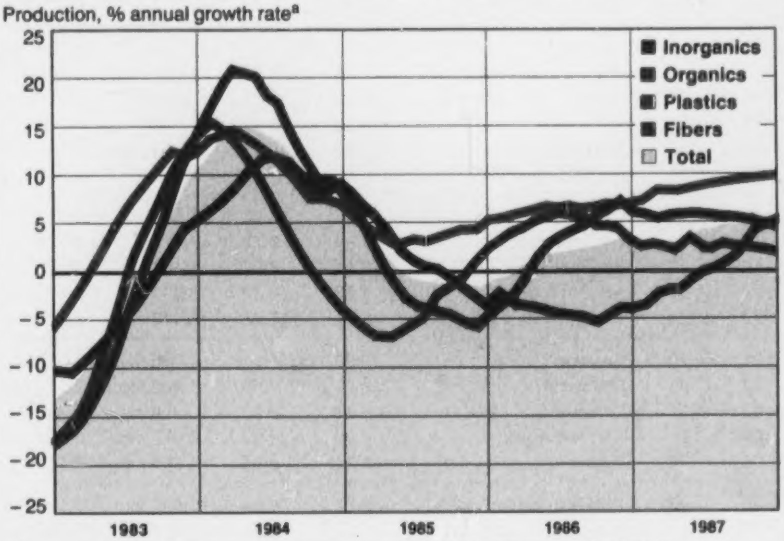
Industrial gases, organic chemicals, plastics materials, and agricultural chemicals experienced some of the largest gains. Plastics materials output was up a whopping 15%, the fifth high in five years. Overall production of thermoplastic resins was up 10%, led by a 43% increase for styrene-acrylonitrile, a relatively small-volume plastic, and a 19% rise for polyester.

Fertilizer production reversed the decline observed in 1985 and 1986. Output rose in all major categories, reflecting an increase in farm income. Paint and coatings production reached the highest level since 1978, and total output of synthetic fibers was also up. Cellulosic and acrylic fibers were the only categories of man-made fibers that declined in 1987, although polyester output remained well below the level of the early 1980s.

Basic chemicals recovered slightly, with output rising 6%, putting it back to the level it was six years earlier. Production of industrial gases, which was up 17%, paced the increase. Even minerals that had posted losses during the past decade were up.

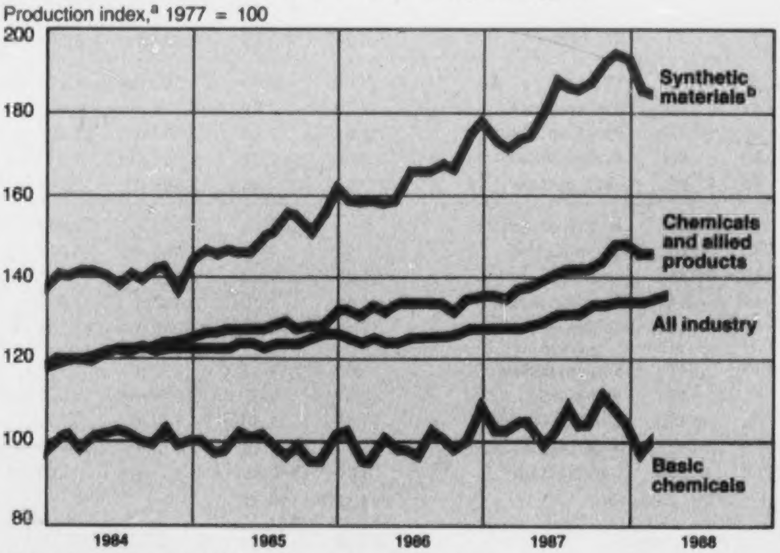
Performance of the chemically related products sector was only slightly better than it was in 1986. Soaps and toiletries output rose just 3%, unlike previous years in the past decade when this category showed annual increases averaging 7%. Drugs and medicines also rose 3%, the same as the average annual increase over the past decade.

Plastics set pace for steady chemical growth in 1987



a Average running annual growth rates in production of major plastics, inorganic and organic chemicals, and all chemicals, and in shipments of man-made fibers. **Sources:** International Trade Commission, Bureau of the Census, Society of the Plastics Industry, Textile Economics Bureau

Synthetic materials lead chemical output higher



a Seasonally adjusted. b Includes plastics, synthetic rubber, and man-made fibers.
Source: Federal Reserve Board

TOP 50 CHEMICALS: 1987 witnessed higher output for all but a handful

Rank			Billions of lb		Common units[b]		Average annual growth			
1987	1986[a]		1987	1986	1987	1986	1986–87	1985–86	1982–87	1977–87
1	1	**Sulfuric acid**	77.49	73.64	38,748 tt	36,822 tt	5.2%	−7.1%	3.1%	1.1%
2	2	**Nitrogen**	47.32	48.62	653 bcf	671 bcf	−2.7	2.4	6.2	8.5
3	4	**Ethylene**	34.99	32.81	34,992 mp	32,811 mp	6.6	9.9	7.4	4.5
4	6	**Ammonia**	32.32	28.01	16,161 tt	14,005 tt	15.4	−19.1	0.5	−0.3
5	3	**Oxygen**	32.28	33.03	390 bcf	399 bcf	−2.3	1.5	2.2	0.2
6	5	**Lime[c]**	30.36	29.67	15,182 tt	14,834 tt	2.3	−6.1	1.5	−2.2
7	7	**Sodium hydroxide**	23.03	21.38	11,517 tt	10,691 tt	7.7	−1.5	4.2	0.9
8	8	**Chlorine**	21.93	20.87	10,963 tt	10,436 tt	5.0	0.4	3.6	0.5
9	9	**Phosphoric acid**	20.95	18.41	10,473 tt	9,206 tt	13.8	−12.5	4.9	2.8
10	10	**Propylene**	18.53	17.34	18,527 mp	17,343 mp	6.8	16.5	8.1	6.3
11	11	**Sodium carbonate[d]**	17.78	16.88	8,891 tt	8,438 tt	5.4	−1.8	2.6	5.5
12	14	**Urea[e]**	14.86	12.06	7,431 tt	6,029 tt	23.3	−9.7	2.8	6.6
13	13	**Nitric acid**	14.20	13.12	7,102 tt	6,562 tt	8.2	−10.9	−0.8	−0.9
14	12	**Ethylene dichloride**	13.81	14.53	13,805 mp	14,529 mp	−5.0	20.1	12.6	5.6
15	15	**Ammonium nitrate[f]**	12.83	11.11	6,416 tt	5,556 tt	15.5	−18.0	−2.0	−1.1
16	16	**Benzene**	11.67	10.23	1,585 mg	1,389 mg	14.1	8.9	8.5	1.1
17	17	**Carbon dioxide[g]**	9.84	9.77	4,922 tt	4,883 tt	0.8	−2.3	5.2	9.6
18	18	**Ethylbenzene**	9.41	8.92	9,409 mp	8,915 mp	5.5	20.7	7.2	5.0
19	19	**Vinyl chloride**	8.23	8.42	8,230 mp	8,415 mp	−2.2	−11.1	10.9	3.8
20	21	**Terephthalic acid[h]**	8.11	7.68	8,110 mp	7,684 mp	5.5	18.4	10.9	1.2
21	20	**Styrene**	8.09	7.84	8,090 mp	7,838 mp	3.2	2.8	6.4	2.5
22	22	**Methanol**	7.29	7.33	7,292 mp	7,327 mp	−0.5	46.5	−0.7	1.6
23	25	**Toluene[i]**	6.73	5.82	928 mg	802 mg	15.7	14.7	5.4	−0.7
24	24	**Formaldehyde[j]**	6.08	5.89	6,077 mp	5,885 mp	3.3	5.0	4.8	1.1
25	26	**Xylene**	5.72	5.55	795 mg	771 mg	3.1	4.5	3.9	1.0
26	23	**Ethylene oxide**	5.62	5.94	5,623 mp	5,943 mp	−5.4	9.4	2.4	3.0
27	27	***p*-Xylene**	5.15	5.00	5,152 mp	4,995 mp	3.1	4.5	9.9	5.9
28	28	**Hydrochloric acid**	4.99	4.83	2,495 tt	2,413 tt	3.4	−14.0	0.4	−0.2
29	29	**Ethylene glycol**	4.52	4.76	4,515 mp	4,759 mp	−5.1	13.9	0.9	3.1
30	30	**Ammonium sulfate**	4.37	4.17	2,183 tt	2,086 tt	4.7	−0.3	4.3	0.8
31	31	**Cumene**	4.15	3.70	4,151 mp	3,695 mp	12.3	10.5	8.6	4.3
32	41	**Methyl *tert*-butyl ether[k]**	3.37	2.24	3,372 mp	2,237 mp	50.7	18.3	32.6	nm
33	33	**Phenol[l]**	3.24	2.92	3,241 mp	2,921 mp	11.0	5.2	9.9	4.3
34	32	**Acetic acid**	3.23	2.93	3,227 mp	2,931 mp	10.1	1.2	3.3	2.7
35	35	**Butadiene[m]**	3.00	2.59	3,002 mp	2,593 mp	15.8	10.8	9.4	−1.5
35	34	**Potash[n]**	3.00	2.65	1,360 tmt	1,202 tmt	13.1	−7.3	−5.3	−4.6
37	35	**Carbon black**	2.72	2.59	2,724 mp	2,585 mp	5.4	0.5	3.4	−1.0
38	37	**Propylene oxide**	2.61	2.48	2,608 mp	2,480 mp	5.2	3.3	9.2	3.6
39	39	**Acrylonitrile**	2.55	2.31	2,551 mp	2,314 mp	10.2	−1.4	4.8	5.3
40	40	**Vinyl acetate**	2.51	2.25	2,505 mp	2,249 mp	11.4	6.5	6.0	5.4
41	38	**Aluminum sulfate**	2.45	2.44	1,223 tt	1,222 tt	0.1	−3.6	1.2	0.2
42	42	**Cyclohexane**	2.25	2.07	2,250 mp	2,071 mp	8.6	25.0	12.0	0.3
43	43	**Acetone**	2.08	1.94	2,082 mp	1,936 mp	7.5	8.3	4.2	1.1
44	44	**Titanium dioxide**	1.90	1.86	952 tt	931 tt	2.3	8.3	7.7	2.9
44	45	**Sodium silicate**	1.90	1.57	948 tt	786 tt	20.6	9.0	7.4	2.4
46	47	**Sodium sulfate[o]**	1.61	1.55	805 tt	775 tt	3.9	−6.3	−1.4	−4.2
47	48	**Adipic acid**	1.57	1.52	1,572 mp	1,522 mp	3.3	4.7	6.3	0.4
48	46	**Calcium chloride[p]**	1.55	1.56	773 tt	780 tt	−0.9	−2.6	−2.0	−4.3
49	49	**Isopropyl alcohol**	1.31	1.28	1,313 mp	1,275 mp	3.0	3.2	−1.0	−3.8
50	50	**Caprolactam**	1.16	0.85	1,161 mp	850 mp	36.6	−21.5	7.9	4.1
TOTAL ORGANICS			**201.85**	**189.17**			**5.5%**	**9.3%**	**7.1%**	**2.7%**
TOTAL INORGANICS			**364.83**	**347.74**			**4.9%**	**−5.7%**	**2.3%**	**−0.1%**
GRAND TOTAL			**566.68**	**536.91**			**5.5%**	**−0.9%**	**4.8%**	**1.3%**

[a] Revised. [b] tt = thousands of tons, bcf = billions of cubic feet, mp = millions of pounds, mg = millions of gallons, tmt = thousands of metric tons. [c] Except refractory dolomite. [d] Natural and synthetic. [e] 100% basis. [f] Original solution. [g] Liquid and solid only. [h] Includes both acid and ester without double counting. [i] All grades. [j] 37% by weight. [k] Production data for earlier years unavailable. [l] Synthetic only. [m] Rubber grade. [n] K_2O basis. [o] High and low purity. [p] Solid and liquid. nm = not meaningful.

PRODUCTION: Last year brought better-than-usual growth for basic chemicals and synthetics

Industrial production indexes, 1977 = 100	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Total index	129.8	125.1	123.7	121.4	109.2	103.1	111.0	108.6	110.7	106.5	100.0	4%	3%
Manufacturing, total	134.7	129.1	126.4	123.4	110.2	102.2	110.5	108.2	111.5	107.1	100.0	4	3
Nondurable manufacturing	136.8	130.1	124.6	122.3	113.7	105.5	109.7	107.0	108.2	105.5	100.0	5	3
Chemicals and products	140.2	132.0	126.4	121.6	114.0	103.8	112.6	106.4	111.4	106.8	100.0	6	3
Chemicals and synthetic materials	135.6	123.8	118.6	114.7	109.1	95.4	109.4	99.4	113.7	108.2	100.0	10	3
Basic chemicals	104.9	98.9	100.0	100.6	95.0	90.6	104.3	107.2	110.1	110.7	100.0	6	0
Alkalies and chlorine	103.4	97.5	97.1	97.8	91.5	83.3	96.1	104.1	113.6	101.7	100.0	6	0
Industrial gases	150.3	128.3	127.0	123.6	114.0	103.9	115.4	105.0	107.2	98.7	100.0	17	4
Inorganic pigments	100.5	99.6	96.2	95.4	91.5	81.7	99.0	97.6	100.8	103.5	100.0	1	0
Inorganic chemicals, nec	98.2	94.1	96.5	97.9	92.9	90.9	104.6	109.4	111.1	115.3	100.0	4	0
Industrial organic chemicals	122.9	112.7	109.2	106.2	104.0	90.3	105.5	89.1	108.1	104.5	100.0	9	2
Synthetic materials	161.7	162.6	149.4	140.3	129.0	108.0	120.2	110.1	125.8	112.2	100.0	12	6
Plastics materials	252.5	220.0	197.4	179.8	158.7	129.9	136.1	122.1	132.6	115.6	100.0	15	10
Synthetic rubber	92.7	96.5	96.8	107.6	98.3	86.8	91.2	93.0	112.1	99.0	100.0	−4	−1
Man-made fibers	104.3	98.5	95.3	94.1	95.4	82.9	104.6	97.3	119.4	110.2	100.0	6	0
Chemical products	152.1	147.5	139.3	132.4	123.2	114.7	116.5	113.7	110.1	106.7	100.0	3	4
Drugs and medicines	138.3	134.8	126.4	121.7	118.8	114.2	112.0	112.9	107.5	105.1	100.0	3	3
Soap and toiletries	188.9	182.9	168.1	155.9	139.9	125.4	129.6	121.5	115.0	106.6	100.0	3	7
Paints	100.5	100.1	98.6	92.9	90.1	83.5	86.7	89.7	95.0	104.7	100.0	0	0
Agricultural chemicals	92.4	85.7	96.1	98.2	86.9	90.2	109.2	107.3	103.9	97.5	100.0	8	−1
Petroleum products	93.5	92.6	86.9	87.4	84.0	84.2	89.4	94.0	101.7	102.5	100.0	1	−1
Rubber and plastics products	163.6	151.4	146.1	143.5	124.3	110.2	116.4	107.8	114.9	107.5	100.0	8	5

nec = not elsewhere classified. **Source:** Federal Reserve Board

MINERALS: Mixed results in 1987 did little to alter long-term decline

Thousands of tons	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Bromine, sold or used[a]	155[b]	155	160	193	185	200	189	189	249	223	217	0%	−3%
Calcium chloride, production[c,d]	773[b]	780	940	1,036	912	853	917	811	981	1,031	968	−1	−2
Iodine, consumption[e,f]	na	na	na	3.8	4.1	3.4	4.4	4.4	4.4	4.0	4.3	na	na
Imports[f]	1.3[b]	1.6	2.7	2.6	3.1	2.3	3.0	3.1	3.1	3.4	3.5	−19	−9
Lime, sold or used[g]	15,502	14,000	15,713	15,922	14,867	14,075	18,890	19,037	20,983	20,484	19,987	11	−3
Lithium, consumption[e,h]	3.0[b]	2.6	2.5	3.2	2.2	2.0	3.2	3.0	3.2	3.4	4.1	15	−3
Phosphate rock													
Marketable production	44,000	42,670	56,035	54,230	46,928	41,241	59,110	59,982	56,891	55,156	52,091	3	−2
Exports	9,000	8,651	10,071	12,707	13,239	10,849	11,458	15,737	15,827	14,187	14,584	4	−5
Potash (K_2O equivalent)[i]													
Production	1,500[b]	1,325	1,429	1,724	1,575	1,967	2,377	2,468	2,453	2,484	2,457	13	−5
Imports[j]	4,300[b]	4,643	5,063	5,323	4,894	4,253	5,287	5,481	5,693	5,189	5,076	−7	−2
Apparent consumption	5,390[b]	5,338	5,893	6,638	6,231	5,647	6,849	6,999	7,626	6,840	6,605	1	−2
Salt, total sold or used[k]	35,700[b]	36,663	40,067	39,225	34,573	37,894	38,915	40,396	45,820	42,896	43,439	−3	−2
Evaporated[l]	5,700[b]	6,233	6,010	5,492	5,532	5,305	6,209	6,358	6,248	5,872	5,704	−9	0
Rock[l]	12,100[b]	13,565	14,023	13,337	12,446	12,884	11,871	11,806	14,891	14,688	14,958	−11	−2
Salt in brine[l]	17,850[b]	16,865	20,034	20,397	16,595	19,705	20,835	22,231	24,681	22,336	22,777	6	−2
Sodium carbonate, production[d]	8,500	8,438	8,511	8,511	8,467	7,819	8,281	8,275	8,253	8,290	8,040	1	1
Sulfur, production[m]	11,617	12,221	12,797	11,742	10,240	10,788	13,388	13,080	13,339	12,318	11,824	−5	0
Apparent consumption[n]	12,481	11,669	13,192	13,976	12,112	11,088	14,093	15,056	15,145	13,889	12,850	7	0
Frasch, production	3,530	4,457	5,524	4,622	3,530	4,641	6,997	7,044	7,007	6,226	6,520	−21	−6
Recovered elemental, production	6,790	6,411	5,857	5,747	5,462	4,855	4,695	4,490	4,486	4,478	3,995	6	5
Other, production	1,296	1,354	1,416	1,372	1,249	1,293	1,695	1,547	1,845	1,615	1,310	−4	0

a Elemental bromine sold as such or used in preparation of bromine compounds by primary producers. **b** Preliminary figure. **c** 75% $CaCl_2$ equivalent. **d** Natural and synthetic. **e** Estimated apparent consumption. **f** Crude elemental iodine. **g** Includes Puerto Rican production. **h** Lithium content basis. **i** Includes muriate and sulfate of potash, potassium magnesium sulfate, and parent salts; excludes other chemical compounds containing potassium. **j** Includes nitrate of potash. **k** Total obtained by all recovery methods that was sold or used by domestic producers (figures differ slightly from U.S. production figures); figures for 1973–81 include Puerto Rican production. **l** Sold or used as such. **m** Sulfur content basis. **n** Calculated from shipments plus imports minus exports (sulfur content basis). **na** = not available. **Source:** Bureau of Mines

ORGANIC CHEMICALS: Production was strongly higher last year for many products

Millions of lb unless otherwise noted	Production											Annual change	
	1987^a	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Acetic acid, synthetic	3,227	2,728	2,897	2,619	2,807	2,748	2,705	2,977	3,265	2,776	2,570	18%	2%
Acetone	2,078	1,910	1,788	1,862	1,859	1,694	2,144	2,076	2,653	2,519	2,219	9	−1
Acrylonitrile	2,551	2,182	2,349	2,219	2,146	2,035	1,997	1,830	2,018	1,752	1,646	17	4
Aniline	923	824	716	786	663	557	634	659	690	606	584	12	5
Benzene, mg^{b,c}	1,585	1,362	1,283	1,318	1,232	1,052	1,308	1,534	1,612	1,435	1,371	16	1
Bisphenol A	1,000	956	949	762	643	480	555	530	576	471	455	5	8
1,3-Butadiene^d	3,002	2,546	2,340	2,452	2,353	1,915	2,986	2,799	3,583	3,515	3,259	18	−1
1-Butanol	935	881	716	908	833	730	809	790	766	756	660	6	4
Caprolactam	1,161	1,109	1,089	1,027	977	793	928	905^e	945	919	867	5	3
Carbon tetrachloride	673	627	646	713	573	587	726	710	714	737	809	7	−2
Chloroform	462	422	275	405	362	299	405	273	356	349	302	9	4
Cumene	4,151	3,745	2,627	3,754	3,345	2,743	3,309	3,459	3,917	3,380	2,644	11	5
Cyclohexane	2,250	2,070	1,657	1,994	1,656	1,275	1,820	1,964	2,425	2,332	2,265	9	0
Dioctyl phthalate	350	296	275	301	300	266	304	353	336	409	400	18	−1
Dodecylbenzene^e	na	851	547	561	545	509	535	563^f	627	526	526	na	na
Ethanol, synthetic	na	529	649	1,060	1,077	1,023	1,317	1,451	1,408	1,267	1,339	na	na
Ethanolamines^g	628	543	537	504	468	416	429	376	420	362	308	16	7
Ethylbenzene	9,332	9,020	7,386	7,562	7,876	6,656	7,813	7,642	8,448	8,385	8,312	3	1
Ethyl chloride	164	164	171	290	282	339	324	396	582	540	612	0	−12
Ethylene	34,992	32,859	29,847	31,383	28,680	24,501	29,418	28,667	29,904	25,955	25,172	6	3
Ethylene dichloride	13,806	12,940	12,101	10,710	11,506	7,619	9,974	11,108	11,794	11,001	10,997	7	2
Ethylene glycol	4,515	4,771	4,178	4,823	4,425	4,309	4,143	4,386	4,729	3,904	3,675	−5	2
Ethylene oxide	5,623	5,430	5,430	5,699	5,534	4,987	4,937	5,220	5,665	5,012	4,364	4	3
2-Ethylhexanol	638	571	536	541	387	325	389	367	318	420	493	12	3
Formaldehyde, 37%^{h}	6,064	5,549	5,606	5,815	5,465	4,817	5,721	5,555	5,971	6,381	6,046	9	0
Isopropyl alcohol	1,313	1,301	1,235	1,394	1,209	1,380	1,669	1,836	1,900	1,730	1,888	1	−4
Maleic anhydride	387	359	394	359	299	260	293	304	323	341	294	8	3
Methanol, synthetic	7,292	7,205	5,003	8,186	7,982	7,555	8,577	7,153	7,367	6,443	6,453	1	1
Methyl chloride	455	605	410	482	409	366	405	362	463	454	476	25	0
Methyl ethyl ketone	na	600	537	543	531	468	614	692	716	644	635	na	na
Methyl methacrylate	1,029	943	858	917	844	721	592	564	633	570	478	9	8
Methylchloroform	694	652	869	675	586	595	611	587	656	661	512	6	3
Methylene chloride	516	566	467	607	584	532	891	780	931	na	745	−9	−4
Perchloroethylene	473	414	678	573	547	585	691	765	773	725	614	14	−3
Phenol, synthetic^i	3,241	3,115	2,841	2,889	2,638	2,023	2,578	2,568	2,981	2,682	2,338	4	3
Phthalic anhydride	1,035	863	820	870	838	684	870	818	1,013	978	926	20	1
Propylene^j	18,460	16,522	14,887	15,559	13,959	12,535	13,482	13,676	14,198	13,014	13,328	12	3
Propylene glycol	808	573	500	462	484	400	473	488	610	547	489	41	5
Styrene, monomer	8,015	7,888	7,622	7,709	6,802	5,942	6,679	6,856	7,484	7,186	6,867	2	2
Terephthalic acid, dimethyl ester^k	8,110	6,257	6,490	5,912	5,626	4,843	6,235	6,054	6,159	5,954	5,410	30	4
Toluene, mg^{b,l}	928	611	698	728	780	714	852	1,010	1,001	1,046	1,008	52	−1
Vinyl acetate	2,505	1,710	2,112	2,024	1,963	1,876	1,936	1,922	1,982	1,692	1,566	46	5
Vinyl chloride	8,230	8,439	9,463	6,084	6,875	4,902	6,874	6,466	6,389	6,941	5,986	−2	3
***o*-Xylene**	947	788	675	688	781	802	918	995	1,082	1,013	985	20	0
***p*-Xylene**	5,152	5,035	4,779	4,264	4,114	3,391	4,532	4,238	4,650	3,516	3,172	2	5

a Preliminary. b Tar distillers and coke-oven operators not included. c Specification grades. d Rubber grade. e Includes straight-chain dodecylbenzene, tridecylbenzene, and other straight-chain alkylbenzenes. f Preliminary figure, final figure not available. g Mono-, di-, and triethanolamines. h By weight. i Does not include data for coke ovens and gas-retort ovens. j All grades. k Includes both acid and dimethyl ester (DMT), without double counting. l High-purity toluene, includes material used in blending motor fuel. **mg** = millions of gallons. **na** = not available.
Source: International Trade Commission

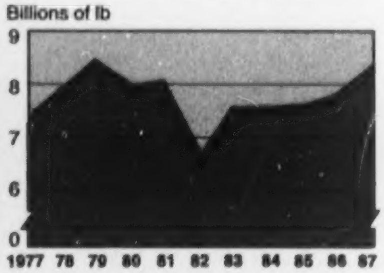
INORGANICS: Despite 1987's growth, output of many products was below levels of late 1970s

Thousands of tons unless otherwise noted	Production											Annual change	
	1987^{a}	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Aluminum sulfate^{b}	1,223	1,222	1,268	1,129	1,119	1,154	1,294	1,286	1,315	1,309	1,255	0%	0%
Ammonia,^{c,d} 100%	16,161	14,474	17,319	16,692	14,072	15,801	19,044	19,653	18,634	17,119	17,756	12	−1
Ammonium nitrate,^{e} 100%	6,416	6,089	6,776	7,146	6,240	7,091	8,861	9,128	8,293	7,210	7,177	5	−1
Ammonium sulfate,^{d,f} 100%	2,183	2,080	2,093	2,067	1,956	1,768	2,185	2,136	2,363	2,449	2,264	5	0
Chlorine gas^{g}	10,980	10,436	10,402	10,700	9,960	9,176	10,763	11,421	12,291	11,052	10,573	5	0
Hydrochloric acid,^{h} 100%	2,495	2,413	2,807	2,732	2,468	2,450	2,574	2,888	3,090	2,793	2,668	3	−1
Hydrogen,^{i,j} bcf, 100%	164	142	121	109	103	88	105	107	106	90	85	15	7
Nitric acid,^{k} 100%	7,102	6,734	7,631	7,726	6,768	7,390	9,093	9,231	8,916	7,934	7,987	5	−1
Nitrogen gas,^{i,l} bcf, 100%	653	617	665	661	560	483	490	479	427	379	328	6	7
Oxygen,^{i,j} bcf, 100%	390	347	393	375	346	349	431	431	456	430	392	12	0
Phosphoric acid, 100% P_2O_5	10,473	9,578	10,518	11,370	9,767	8,253	9,958	10,848	10,318	9,637	8,745	9	2
Phosphorus^{m}	343	364	359	386	366	361	426	432	460	441	430	−6	−2
Sodium chlorate, 100%	262	267	259	295	323	291	297	312	269	265	251	−2	0
Sodium hydroxide, 100%	11,518	10,691	10,811	10,914	10,039	9,385	10,621	11,625	12,759	11,309	11,000	8	0
Sodium phosphate^{n}	565	617	625	675	669	651	696	727	757	739	717	−8	−2
Sodium silicate^{o}	948	791	737	685	710	664	771	805	813	829	760	20	2
Sodium sulfate,^{p} 100%	805	837	1,203	901	914	864	1,111	1,140	1,121	1,174	1,199	−4	−4
Sulfuric acid,^{q} 100%	38,750	35,759	39,651	41,802	36,583	33,233	40,742	44,158	43,204	41,314	38,337	8	0
Titanium dioxide,^{r} 100%	952	931	860	835	760	660	761	727	742	701	687	2	3
Urea	7,441	6,264	6,678	7,433	6,137	6,470	8,062	7,830	7,000	6,273	5,072	19	4

Note: bcf = billions of cubic feet. a Preliminary. b Commercial, 17% Al_2O_3; includes municipalities. c Synthetic anhydrous. d Excludes by-product ammonia liquor and ammonium sulfate. e Original solution. f Synthetic and noncoke by-product. g Includes quantities liquefied for use, storage, or shipment. h Includes anhydrous hydrochloric acid production. i High- and low-purity gas. j Liquid and gas; excludes amounts vented and used as fuel, and amounts produced in petroleum refineries for captive use. k Includes unspecified amounts of nitric acid produced but not withdrawn from the system. l Excludes amounts produced and consumed in making synthetic ammonia or ammonia derivatives. m Elemental, white (yellow), and red. n Tripolyphosphate (100% $Na_5P_3O_{10}$). o Soluble silicate glass (water glass), solid and liquid (anhydrous); excludes amounts produced and consumed in making meta-, ortho-, and sesquisilicates. p Anhydrous, high and low purity, and Glauber's salt. q Gross (new and fortified). r Composite and pure. **Sources:** Department of Commerce, International Trade Commission

MAN-MADE FIBERS: For three big-volume materials, 1987 was robust

Man-made noncellulosic fibers output

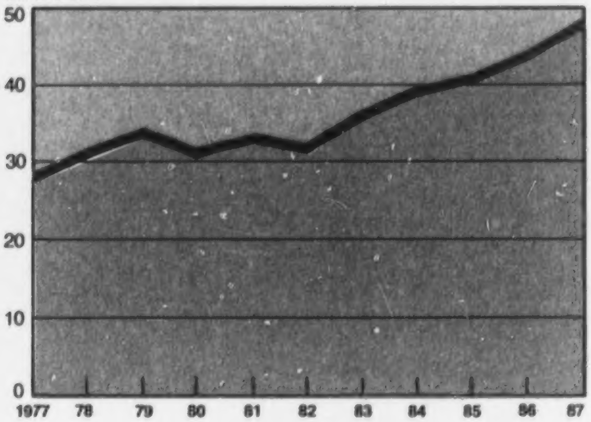


Millions of lb	Production											Annual change	
	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
NONCELLULOSIC FIBERS													
Acrylic^{a}	592	616	631	671	671	624	691	779	761	726	709	−4%	−2%
Nylon^{b}	2689	2514	2343	2412	2419	1927	2332	2358	2,720	2550	2326	7	1
Olefins^{c}	1495	1393	1249	997	906	723	785	748	759	692	635	7	9
Polyester	3541	3305	3341	3392	3544	3169	4176	3989	4,178	3800	3642	7	0
CELLULOSIC FIBERS													
Acetate^{d}	607	619	558	199	229	196	261	316	324	308	290	−2	8
Rayon				421	401	388	509	490	606	597	598		
GLASS FIBER	na	na	na	1394	1168	899	1041	867	1,014	923	787	na	na
TOTAL^{e}	**8924**	**8447**	**8122**	**9486**	**9336**	**7926**	**9795**	**9547**	**10,362**	**9596**	**8987**	**6%**	**nc**

Note: Totals may not add because of rounding. a Includes modacrylic. b Excludes aramid in 1983–87. c Includes olefin yarn and monofilaments and olefin and vinyon staple, tow, and fiberfill. d Includes diacetate and triacetate; excludes production for cigarette filters. e Totals for 1985, 1986, and 1987 exclude glass fiber. na = not available. nc = not comparable. **Source:** Textile Economics Bureau

Plastics production

Billions of lb



PLASTICS: Volume rose to record levels for major resins in 1987

Millions of lb[a]	Production 1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	1977–87
THERMOSETTING RESINS													
Epoxy[b]	433	398	385	406	334	286	336	315	361	299	261	9%	5%
Polyester[c]	1,370	1,271	1,223	1,232	1,084	865	997	947	1,147	1,209	1,061	8	3
Urea	1,382	1,271	1,210	1,199	1,172	998	1,165	1,165	1,367	1,122	963	9	4
Melamine	212	173	192	210	180	158	179	167	200	202	200	23	1
Phenolic[d]	2,869[e]	2,735[e]	2,621[e]	2,502[e]	2,477[e]	2,006[e]	2,333[e]	1,499	1,781	1,617	1,458	5	nc
TOTAL	**6,266**	**5,848**	**5,631**	**5,549**	**5,247**	**4,313**	**5,010**	**4,093**	**4,856**	**4,449**	**3,943**	**7**	**nc**
THERMOPLASTIC RESINS													
Polyethylene													
Low density[f]	9,629	8,903	8,889	8,413	8,041	7,503	7,693	7,291	7,793	7,111	6,471	8	4
High density[g]	7,999	7,182	6,671	6,085	5,689	4,928	4,695	4,405	5,010	4,201	3,652	11	8
Polypropylene	6,647	5,812	5,139	4,940	4,433	3,477	3,955	3,648	3,841	3,074	2,747	14	9
Styrene-acrylonitrile	132	92	87	99	93	91	107	111	124	120	115	43	1
Polystyrene	4,782	4,470	4,054	3,838	3,570	3,191	3,621	3,521	4,005	3,823	3,446	7	3
Acrylonitrile-butadiene styrene and other styrene polymers[h]	2,398	2,196	2,036	2,127	1,889	1,380	1,745	1,705	2,107	2,012	1,882	9	2
Polyamide, nylon type	507	465	399	396	321	228	312	274	327	275	254	9	7
Polyvinyl chloride and copolymers	7,971	7,256	6,772	6,760	6,067	5,326	5,707	5,470	6,119	5,723	5,253	10	4
Thermoplastic polyester	1,394	1,175	965	899	778	648	609	na	na	na	na	19	na
Other vinyl resins[i]	212	195	190	187	186	177	208	196	220	197	197	9	1
TOTAL	**41,671**	**37,746**	**35,202**	**33,744**	**31,067**	**26,949**	**28,652**	**26,621**	**29,546**	**26,536**	**24,017**	**10%**	**6%**

Note: Totals are for those products listed and exclude some small-volume plastics. **a** Dry-weight basis unless otherwise specified. **b** Unmodified. **c** Unsaturated. **d** Includes other tar acid resins. **e** Gross-weight basis. **f** Density 0.940 and below. **g** Density above 0.940. **h** Includes styrene-butadiene copolymers and other styrene-based polymers. **i** Includes polyvinyl butyral, polyvinyl formal, and polyvinylidene-chloride. **na** = not available. **nc** = not comparable. **Source:** Society of the Plastics Industry

SYNTHETIC RUBBER: Output of all types rose last year

Thousands of metric tons	Production 1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	1977–87
Styrene-butadiene rubber	850	792	735	958	904	876	1032	1074	1378	1395	1395	7%	−5%
Polybutadiene	371	336	330	359	333	288	342	311	397	378	361	10	0
Nitrile	69	59	53	67	55	45	66	63	75	73	70	17	0
Ethylene-propylene	254	230	215	215	175	123	178	144	175	174	158	10	5
Other[a]	638	596	505	556	468	498	404	423	509	453	432	7	4
TOTAL	**2182**	**2013**	**1838**	**2155**	**1935**	**1830**	**2022**	**2015**	**2534**	**2473**	**2416**	**8%**	**−1%**

a Includes butyl, polychloroprene, polyisoprene, silicone, and other synthetic elastomers. Some values are estimated. **Source:** Rubber Manufacturers Association

FERTILIZERS: Production rebounded a bit during 1987 crop year

Thousands of tons	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
NITROGEN (N)													
Domestic production	10,741	10,425	12,532	10,364	9,855	11,598	13,036	12,323	11,106	10,466	10,789	3%	0%
Imports	3,656	3,979	3,598	3,940	2,654	2,531	2,455	2,566	2,165	1,866	1,842	−8	7
Exports	2,708	2,068	3,227	2,080	2,074	2,499	3,088	2,641	2,468	1,778	1,251	31	8
Domestic supply	11,689	12,336	12,903	12,224	10,435	11,630	12,403	12,248	10,803	10,554	11,380	−5	0
PHOSPHATE (P_2O_5)													
Domestic production	9,903	8,581	10,666	9,611	8,043	7,818	10,471	10,012	9,432	8,245	7,793	15	2
Imports	116	111	141	121	133	193	250	239	236	229	245	6	−7
Exports	4,282	3,768	5,547	4,352	3,916	3,751	4,381	3,925	3,848	3,290	2,501	14	6
Domestic supply	5,739	4,924	5,260	5,380	4,260	4,260	6,340	6,326	5,820	5,184	5,537	17	0
POTASH (K_2O)													
Domestic production	1,311	1,052	1,413	1,653	1,859	1,831	2,262	2,474	2,519	2,176	2,584	25	−7
Imports	4,355	4,759	5,355	5,164	4,402	4,797	5,487	5,403	5,085	4,948	4,955	−8	−1
Exports	599	494	588	528	624	641	876	1,048	999	1,003	994	21	−5
Domestic supply	5,067	5,317	6,180	6,289	5,637	5,987	6,873	6,829	6,605	6,121	6,545	−5	−3

Note: Years ending June 30. **Source:** Department of Agriculture

NITROGEN: Output edged higher but remained well below recent peak

	Production											Annual change	
Thousands of tons (N)	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Ammonia[a]	4,857	4,610	5,255	4,179	3587	5,032	5,348	5,270	4,603	4,063	4,307	5%	1%
Ammonium nitrate[b,c]	667	704	836	913	943	1,105	1,157	1,096	1,137	1,044	1,169	−5	−5
Ammonium sulfate[c]	478	482	484	517	395	432	502	521	509	497	547	−1	−1
Urea	1,687	1,624	1,999	1,786	1692	1,684	1,383	1,572	1,201	1,001	937	4	6
All other	3,052	3,005	3,958	2,969	3238	3,345	3,964	3,864	3,656	3,871	3,829	2	−2
TOTAL	**10,741**	**10,425**	**12,532**	**10,364**	**9855**	**11,598**	**12,354**	**12,323**	**11,106**	**10,476**	**10,789**	**3%**	**0%**

Note: Years ending June 30. a Includes aqueous solutions. b Includes ammonium nitrate-limestone mixtures. c Adjusted for estimated quantity going into nonfertilizer uses. **Source:** Department of Agriculture

PHOSPHATE: Production overall recovered part of ground lost in 1986

	Production											Annual change	
Thousands of tons (P_2O_5)	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Ammonium phosphate[a]	5448	4984	6,525	6156	5026	4434	6,243	5,519	5082	4548	4118	9%	3%
Concentrated superphosphate	1091	1093	1,145	1172	1184	1151	1,694	1,737	1901	1768	1750	0	−5
Normal and enriched superphosphate	138	70	102	113	110	153	376	384	320	303	376	97	−10
All other	3226	2434	2,894	2170	1723	2080	2,613	2,372	2129	1626	1549	33	8
TOTAL	**9903**	**8581**	**10,666**	**9611**	**8043**	**7818**	**10,926**	**10,012**	**9432**	**8245**	**7793**	**15%**	**2%**

Note: Years ending June 30. a Liquid and solid, excluding that combined with potash salts in the process of manufacture. **Source:** Department of Agriculture

POTASH: Total production made big gain, but was still far under earlier levels

	Production											Annual change	
Thousands of tons (K_2O)	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Potassium chloride	1035	762	1107	1248	1456	1383	2007	1874	2082	1770	2098	−36%	−7%
Potassium sulfate	241	255	271	370	368	413	481	565	402	371	451	−5	−6
All other	35	35	35	35	35	35	35	35	35	35	35	0	0
TOTAL	**1311**	**1052**	**1413**	**1653**	**1859**	**1831**	**2523**	**2474**	**2519**	**2176**	**2584**	**25%**	**−7%**

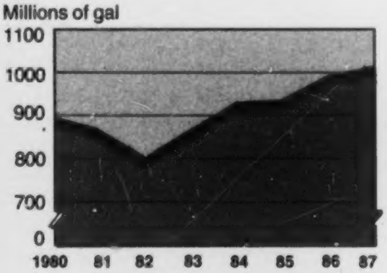
Note: Years ending June 30. **Source:** Department of Agriculture

PESTICIDES: Production of herbicides and insecticides fell in 1986, but fungicides rose

Millions of lb	Production											Annual change	
	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	1985–86	1976–86
Herbicides[a]	725	756	716	604	623	839	806	657	664	674	656	−4%	1%
Insecticides[b]	342	370	350	306	379	448	506	617	605	570	566	−8	−5
Fungicides	113	109	123	106	111	143	156	155	148	143	142	4	−2
TOTAL	**1180**	**1235**	**1189**	**1017**	**1113**	**1430**	**1468**	**1429**	**1416**	**1388**	**1364**	−4%	−1%

a Includes plant growth regulators. b Includes rodenticides, soil conditioners, and fumigants. **Source:** International Trade Commission

Paints and coatings shipments



COATINGS: Shipments edged up to highest level since 1978

Millions of gal	Shipments											Annual change	
	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Architectural	510	501	477	457	433	374	417	439	472	na	na	2%	na
Product[a]	360	350	317	336	294	280	312	316	351	na	na	3	na
Special purpose	133	136	145	145	130	129	129	135	116	na	na	−2	na
TOTAL	**1004**	**987**	**939**	**938**	**857**	**783**	**858**	**890**	**939**	**1033**	**844**	2%	2%

a For original equipment manufacturers. **Source:** Department of Commerce

AEROSOLS: Total volume continued steady rise begun in 1983

Millions of units	Production											Annual change	
	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–87	1977–87
Personal products	964	952	879	832	747	628	645	637	772	729	720	1%	3%
Household products	640	635	630	603	586	556	575	580	653	628	600	1	1
Automotive and industrial products	379	375	342	337	303	286	302	310	300	275	230	1	5
Paints and finishes	307	297	290	307	300	295	313	310	302	309	331	3	−1
Insect sprays	190	193	190	184	180	166	173	150	199	132	120	−2	5
Food products	140	136	140	138	132	131	145	130	141	143	125	3	1
Animal products	22	22	15	16	19	19	14	15	18	15	18	0	2
Miscellaneous	80	18	23	15	15	13	28	30	14	a	5	344	32
TOTAL	**2722**	**2628**	**2509**	**2432**	**2282**	**2094**	**2195**	**2162**	**2399**	**2231**	**2149**	4%	2%

a Not shown separately. **Source:** Chemical Specialties Manufacturers Association

CHLOROFLUOROCARBONS: Poundage continued to recover from low point in 1982

Millions of lb	Production											Annual change	
	1987[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1986–37	1977–87
Chlorodifluoromethane (F-22)	284	271	235	254	236	174	252	227	211	206	179	5%	5%
Dichlorodifluoromethane (F-12)	368	322	302	337	290	258	325	295	294	327	358	14	0
Trichlorofluoromethane (F-11)	223	202	176	185	215	140	163	158	167	194	213	10	0
All other fluorinated hydrocarbons[b]	na	344	306	337	279	na	na	na	202	189	171	na	na
TOTAL	**na**	**1139**	**1019**	**1113**	**1020**	**na**	**na**	**na**	**874**	**916**	**921**	**na**	**na**

a Preliminary. b Includes other fluorohalogenated hydrocarbons. **na** = not available. **Source:** International Trade Commission

2 $ Finances of the U.S. Chemical Industry

Chemical industry gets its act together

Chemical company executives probably have had their 1987 calendars bronzed and placed on shelves with other favored mementos, such as baby shoes and pictures of their children and grandchildren.

Last year proved to be one of the best years for the chemical industry in the past decade. Demand surged, prices increased mightily, and what was not sold in the U.S. could be shipped abroad, where it could compete with products from other countries because the dollar had weakened. And although imports of chemicals into the U.S. continued to increase, that increase was less than the improvement in export growth.

The result was that plant capacity utilization increased throughout the year, until by the end of 1987 many plants, especially those making ethylene and downstream plastics, were operating full out. As a result, plant efficiencies increased and profitability soared.

1987 finally saw the end of deflation in the chemical industry, as prices increased to the point that, by the end of the year, price growth was more than making up for the poor performance of the previous few years.

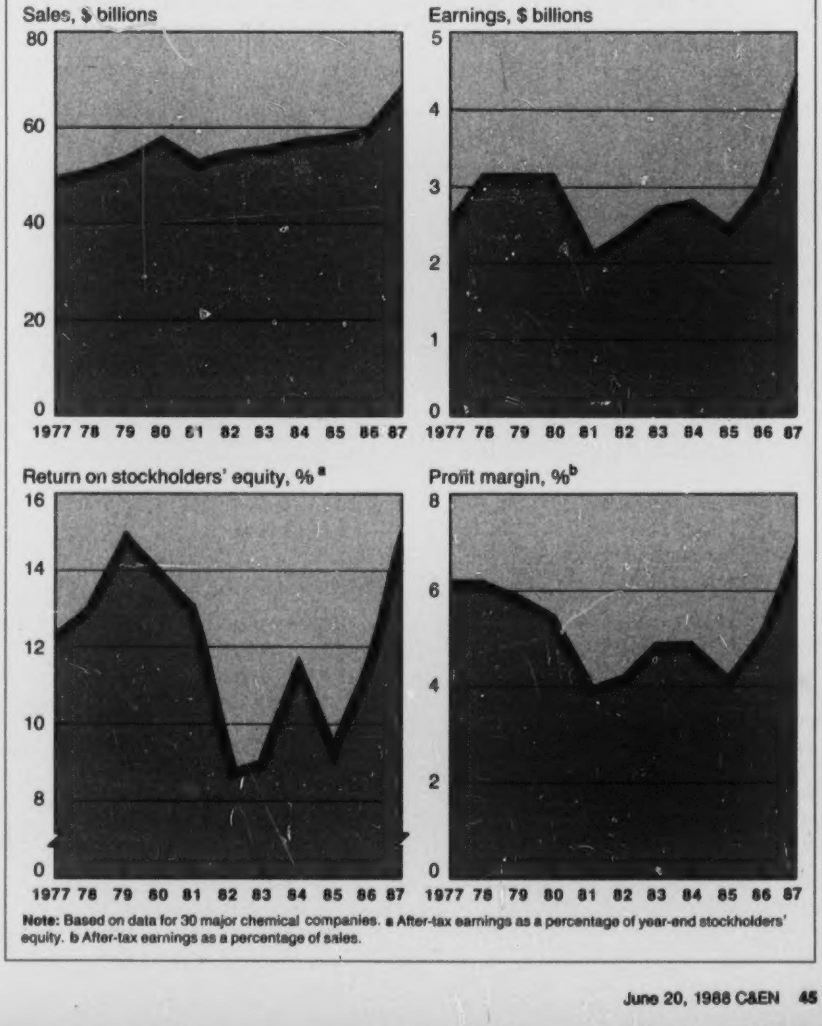
As a result, in 1987~~,~~ sales for the U.S. chemical industry had the greatest year-to-year increase since the inflation-driven gains of the late 1970s. Only this time around, inflation was not general throughout the economy as it was in the late 1970s, when sales were increasing but physical volume was essentially flat. The increases for the chemical industry, therefore, were much more real. Sales for 30 chemical companies tracked by C&EN climbed an average 12% last year.

Earnings were even better. Earnings leverage brought on by a slimmed down work force and improved plant efficiencies, plus selling prices that were rising faster than raw material costs, served to push earnings up an average of about 50% for the industry.

Because of efficiencies brought about by increased plant utilization rates and the continued eye on such internal costs as employment, profitability for the chemical industry soared. Profit margins increased to about 6.7% from just 5.0% in 1986. And return on equity jumped to 15.2% from the year-earlier level of 11.7%.

Thus far, it looks as if the good times of 1987 are easily going to carry through 1988. Chemical prices are still rising faster than general inflation rates; capacity use is high enough that some firms are announcing plans for new plants; the chemical trade surplus is continuing to grow; and sales and earnings are off to a better start than last year.

A surge in earnings last year spurred chemical companies' profitability to the highest level in more than a decade



Note: Based on data for 30 major chemical companies. **a** After-tax earnings as a percentage of year-end stockholders' equity. **b** After-tax earnings as a percentage of sales.

TOP 100 CHEMICAL PRODUCERS: Mergers, broad industry restructuring resulted in considerable

Rank[a] 1987	Rank[a] 1986		Chemical sales 1987 ($ millions)	Change from 1986	Chemical sales as % of total sales	Industry classification	Chemical operating profits[b] ($ millions)	Change from 1986	Chemical operating profits as % of total operating profits	Operating profit margin[c]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[d]
1	1	**Du Pont**	$13,051	10.2%	42.8%	Diversified	$2314	31.2%	57.7%	17.7%	$9265	36.9%	25.0%
2	2	**Dow Chemical**	10,847	22.4	81.1	Basic chemicals	1930	97.3	84.2	17.8	9379	65.3	20.6
3	3	**Exxon**	7,177	18.1	8.7	Petroleum	1087	33.0	14.2	15.1	6285	8.5	17.3
4	4	**Union Carbide**	6,177[e]	23.5	89.3	Basic chemicals	872	16.6	97.4	14.1	6219	78.8	14.0
5	5	**Monsanto**	5,163	9.8	67.6	Basic chemicals	766	−14.5	104.4	14.8	3995	47.3	19.2
6	29	**Hoechst Celanese**	4,284	221.9	93.2	Basic chemicals	na	na	na	na	na	na	na
7	6	**BASF**	3,816	14.3	88.0	Basic chemicals	na	na	na	na	na	na	na
8	7	**Shell Oil**	3,578	8.7	17.2	Petroleum	600	−7.4	29.8	16.6	3681	13.7	16.3
9	8	**Amoco**	3,494	19.3	15.6	Petroleum	704	50.7	25.4	20.1	2689	10.8	26.2
10	16	**Occidental Petroleum**	2,991	43.2	16.9	Petroleum	398	126.7	51.6	13.3	2471	14.8	16.1
11	12	**Mobil**	2,926	22.4	5.2	Petroleum	433	111.2	10.2	14.8	2316	5.6	18.7
12	10	**Allied-Signal**	2,795	−0.9	25.1	Diversified	306	−11.6	40.8	10.9	2043	20.0	15.0
13	11	**W. R. Grace**	2,794	12.1	61.9	Specialty chemicals	357	25.3	81.5	12.8	1960	43.8	18.2
14	15	**General Electric**	2,751[e]	18.0	6.8	Diversified	507	19.6	11.4	18.4	3891	10.0	13.0
15	13	**Eastman Kodak**	2,600	9.3	19.5	Photo equipment	388	70.9	18.4	14.9	2514	17.4	15.4
16	14	**Chevron**	2,593	9.0	9.2	Petroleum	397	170.1	12.0	15.3	1754	5.1	22.6
17	17	**Rohm & Haas**	2,203	6.6	100.0	Basic chemicals	323	15.4	100.0	14.7	1587	81.2	20.4
18	19	**American Cyanamid**	1,960	7.6	47.1	Basic chemicals	193	43.3	41.3	9.8	1387	33.6	13.9
19	—	**Arco Chemical**	1,952	26.7	100.0	Basic chemicals	398	63.1	100.0	20.4	1746	68.9	22.8
20	21	**Bayer USA**	1,951	9.3	46.5	Basic chemicals	84[f]	0.0	68.3	4.3	na	na	na
21	23	**Phillips Petroleum**	1,928	13.5	18.0	Petroleum	482	61.2	44.2	25.0	1165	9.6	41.4
22	20	**Air Products[g]**	1,919	6.8	89.2	Basic chemicals	373	2.8	116.7	19.4	2311	85.5	16.1
23	33	**Quantum Chemical**	1,875	72.6	73.1	Basic chemicals	348	180.5	91.5	18.5	1483	57.5	23.4
24	24	**Borden**	1,857	13.4	28.5	Dairy products	208	18.2	33.9	11.2	1121	27.0	18.6
25	27	**B. F. Goodrich**	1,741	19.4	80.3	Rubber products	210	57.3	92.1	12.1	1280	66.0	16.4
26	22	**Hercules**	1,686	−1.3	62.6	Basic chemicals	134	32.7	64.4	7.9	1318	37.7	10.2
27	26	**Ashland Oil**	1,643	11.2	22.9	Petroleum	90	26.8	33.6	5.5	603	14.9	14.9
28	25	**Ciba-Geigy**	1,620	8.7	57.4	Specialty chemicals	na	na	na	na	na	na	na
29	30	**Texaco**	1,587	24.1	4.6	Petroleum	129	41.8	1.9	8.1	1182	3.5	10.9
30	28	**FMC**	1,488	6.4	48.0	Machinery	242	8.0	69.6	16.3	1335	51.5	18.1
31	31	**Ethyl**	1,406	10.5	54.5	Basic chemicals	258	4.2	65.8	18.3	1018	51.4	25.3
32	18	**Atlantic Richfield**	1,379	33.9	8.2	Petroleum	na	na	na	na	na	na	na
33	34	**Dow Corning**	1,303	20.1	100.0	Specialty chemicals	135[f]	22.1	100.0	10.4	na	na	na
34	72	**Rhône-Poulenc**	1,300	242.1	100.0	Specialty chemicals	na	na	na	na	na	na	na
35	32	**Olin**	1,232	10.6	63.8	Basic chemicals	99	24.1	66.4	8.0	924	54.8	10.7
36	35	**International Minerals[h]**	1,214	12.7	74.1	Agrochemicals	104	197.4	58.8	8.5	1769	72.7	5.9
37	36	**National Starch**	1,208	13.6	100.0	Specialty chemicals	175	25.0	100.0	14.5	941	100.0	18.6
38	37	**Unocal Corp.**	1,071	1.4	11.4	Petroleum	27	−41.3	14.9	2.5	648	6.4	4.2
39	58	**Huntsman Chemical**	1,022	79.3	100.0	Basic chemicals	na	na	na	na	na	na	na
40	—	**Akzo**	992	26.9	100.0	Basic chemicals	42	26.3	100.0	4.3	na	na	na
41	41	**Aluminum Co. of America**	982[e]	16.9	12.6	Nonferrous metals	63	284.0	9.2	6.4	2444	24.7	2.6
42	40	**PPG Industries**	953	13.0	18.4	Glass products	140	35.9	18.0	14.7	1019	20.4	13.7
43	—	**BP America**	943	48.5	6.1	Petroleum	32	−38.5	1.4	3.4	na	na	na
44	39	**Lubrizol**	940	5.7	91.9	Specialty chemicals	140	−0.1	110.5	14.8	649	69.1	21.5
45	46	**Aristech**	919	22.4	100.0	Basic chemicals	120	23.1	100.0	13.1	na	na	na
46	74	**Freeport-McMoRan**	860	129.8	56.8	Agrochemicals	106	40.8	33.5	12.4	714	22.6	14.9
47	48	**NL Industries**	859	17.1	62.7	Petroleum services	209	23.5	140.7	24.4	734	56.3	28.5
48	42	**Pennwalt**	846	8.9	74.1	Basic chemicals	103	10.6	74.4	12.2	716	68.7	14.4
49	47	**Nalco Chemical**	842	14.4	100.0	Specialty chemicals	131	21.2	100.0	15.6	747	100.0	17.5
50	44	**Reichhold Chemicals**	837	9.3	100.0	Basic chemicals	na	na	na	na	na	na	na

a Revised from C&EN, May 2. b Operating profit is sales less administrative expenses and cost of sales. c Operating profit from chemicals as a percentage of chemical sales. d Chemical operating profit as a percentage of identifiable chemical assets. e Chemical sales include significant amounts of nonchemical products. f Chemical net income. g Fiscal year ends Sept. 30. h Fiscal year ends June 30. i Does not include all chemical sales. j Fiscal year ends Nov. 30. k Sales are only for the period between formation of the company April 6, 1987, and end of fiscal year Sept. 30. l Fiscal year ends Oct. 31. m For fiscal year ended Feb. 28, 1987. na = not available. nm = not meaningful. def = deficit.

changes in rankings last year

Rank 1987	Rank 1986		Chemical sales 1987 ($ millions)	Change from 1986	Chemical sales as % of total sales	Industry classification	Chemical operating profits[b] ($ millions)	Change from 1986	Chemical operating profits as % of total operating profits	Operating profit margin[c]	Identifiable chemical assets ($ millions)	Chemical assets as % of total assets	Operating return on chemical assets[d]
51	44	**CF Industries**	$810	5.7%	100.0%	Agrochemicals	$ 4	def	100.0%	0.5%	$856	100.0%	0.5%
52	43	**Cabot**[g]	800	4.1	56.2	Specialty metals	122	−11.2	92.3	15.3	563	38.5	21.7
53	49	**Eli Lilly**	748	7.1	20.5	Drugs	85	60.2	8.8	11.3	724	13.8	11.7
54	53	**International Flavors**	746	20.2	100.0	Specialty chemicals	184	27.2	100.0	24.6	665	76.1	27.6
55	51	**Morton Thiokol**[h]	744	14.2	37.5	Diversified	130	48.5	50.0	17.4	698	41.9	18.6
56	62	**Polysar**	720	34.5	100.0	Basic chemicals	na	na	na	na	na	na	na
57	50	**Engelhard**	712	7.0	28.7	Specialty metals	87	13.5	83.2	12.3	677	55.6	12.9
58	56	**Georgia Gulf**	707	21.3	100.0	Basic chemicals	163	125.0	100.0	23.0	309	100.0	52.7
59	59	**Solvay America**	700[e]	27.3	100.0	Basic chemicals	na	na	na	na	na	na	na
60	52	**Terra Chemicals**	679	8.5	100.0	Agrochemicals	na	na	na	na	na	na	na
61	69	**American Petrofina**	670	51.9	27.0	Petroleum	203	282.3	126.6	30.3	280	15.3	72.5
62	55	**Koppers**	662	12.4	43.7	Diversified	31	−20.8	22.5	4.7	na	na	na
63	61	**Witco**	624[i]	14.6	43.7	Specialty chemicals	61	35.6	49.9	9.7	332	31.5	18.2
64	59	**Vista Chemical**[h]	609	10.7	100.0	Basic chemicals	119	31.2	100.0	19.6	500	100.0	23.8
65	83	**Henkel**	600	126.4	100.0	Specialty chemicals	na	na	na	na	na	na	na
66	63	**H. B. Fuller**[j]	597	13.0	100.0	Specialty chemicals	48	20.9	100.0	8.0	330	100.0	14.5
67	—	**Avery Inc.**[g]	591	nm	98.4	Agrochemicals	na	na	na	na	na	na	na
68	57	**Farmland Industries**	525	−8.6	20.1	Agricultural supplies	1	def	1.7	0.2	316	40.1	0.4
69	70	**Pfizer**	514	23.6	10.4	Drugs	70	71.4	6.6	13.6	483	7.0	14.4
70	64	**Liquid Air**	505	2.8	89.8	Basic chemicals	68	15.7	96.9	13.6	610	81.2	11.2
71	68	**CBI Industries**	492	9.1	42.4	Construction	68	12.5	82.3	13.7	612	48.3	11.1
72	80	**Great Lakes Chemical**	478	59.3	100.0	Specialty chemicals	85	99.1	100.0	17.8	577	100.0	14.7
73	66	**Henley Manufacturing**	464	1.9	76.7	Basic chemicals	39	25.0	101.9	8.5	372	54.2	10.6
73	66	**Kerr-McGee**	464	1.8	17.8	Petroleum	71	9.2	13.7	15.3	549	19.0	12.9
75	71	**Tyler**	436	12.4	39.6	Diversified chemicals	37	35.3	55.5	8.4	203	37.4	18.0
76	73	**GAF**	431	14.3	51.5	Specialty chemicals	130	20.6	82.5	30.1	420	32.3	31.0
76	75	**Merck**	431	20.1	8.5	Drugs	58	15.4	4.2	13.4	429	7.6	13.4
78	76	**Betz Laboratories**	386	12.0	100.0	Specialty chemicals	68	6.8	100.0	17.5	287	100.0	23.6
79	77	**Sun Co.**	371	17.0	3.9	Petroleum	na	na	na	na	na	na	na
80	81	**Ferro**	362[e]	26.9	41.6	Specialty materials	28	25.7	39.0	7.7	187	35.1	14.9
81	—	**Cain Chemical**[k]	357	nm	100.0	Basic chemicals	na	na	na	na	na	na	na
82	79	**Union Camp**	348	14.3	15.1	Diversified	21	236.9	5.6	6.0	279	9.6	7.5
83	82	**Loctite**	338	26.6	100.0	Specialty chemicals	45	23.3	100.0	13.4	297	97.8	15.3
84	78	**Chemed**	336	6.9	85.9	Specialty chemicals	41	25.4	84.5	12.3	177	67.1	23.3
85	88	**Lonza**	312	23.8	100.0	Specialty chemicals	na	na	na	na	na	na	na
86	85	**Vulcan Materials**	298	17.4	32.2	Nonmetallic mineral	33	68.6	17.9	11.0	na	na	na
87	84	**Stepan**	289	11.2	100.0	Specialty chemicals	19	37.4	100.0	6.7	173	100.0	11.1
88	89	**Dexter Corp.**	285	16.5	36.4	Rubber products	29	25.4	30.3	10.3	182	61.9	16.1
89	85	**Petrolite**[l]	248	−2.2	89.1	Specialty chemicals	21	−6.2	99.2	8.6	181	73.0	11.8
90	91	**Sigma-Aldrich**	247	24.1	81.2	Specialty chemicals	64	21.1	88.2	25.8	246	86.1	25.9
91	85	**KaiserTech**	239	−5.9	10.8	Nonferrous metals	16	−51.8	def	6.8	na	na	na
92	92	**Essex Chemical**	191	3.8	91.4	Basic chemicals	28	−13.3	172.9	14.5	143	64.2	19.3
92	93	**Crompton & Knowles**	191	15.8	80.3	Specialty chemicals	20	33.1	70.7	10.4	98	72.3	20.2
94	94	**Georgia-Pacific**	189	21.9	3.3	Wood products	na	na	na	na	na	na	na
95	95	**First Mississippi**	181	18.5	61.2	Agrochemicals	8	−59.6	80.9	4.4	81	27.4	9.9
96	90	**Mississippi Chemical**[h]	174	−23.5	101.8	Farm cooperative	−26	def	def	def	230	100.0	def
97	97	**Quaker Chemical**	148	15.2	100.0	Specialty chemicals	17	21.6	100.0	11.4	118	100.0	14.2
98	96	**Agway**	133	−6.4	4.1	Farm cooperative	na	na	na	na	na	na	na
99	99	**LeaRonal**[m]	128	21.6	100.0	Specialty chemicals	13	21.2	100.0	9.8	75	96.3	16.8
100	98	**UGI Corp.**	116	2.9	27.6	Natural gas	1	def	2.5	1.3	61	10.2	2.4

FINANCIAL ANALYSIS: Solid improvement for most chemical firms in 1987

		Profit margin[a]	Return on investment[b]	Debt as % debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	CAPITAL SPENDING[f] as % of sales	CAPITAL SPENDING[f] as % of net plant	R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
SALES OVER $1 BILLION													
Air Products[g]	1987	7.5%	2.5%	35.0%	22.0%	26.7%	$176	31.6%	15.1%	16.8%	2.7%	78.9%	33.6%
	1986	6.9	3.3	38.9	19.5	25.0	119	32.9	18.5	20.0	3.1	73.3	53.2
American Cyanamid	1987	6.3	5.2	23.1	37.1	25.6	122	35.4	6.4	19.3	7.5	100.9	48.1
	1986	5.3	4.4	25.4	33.6	24.2	111	43.6	6.9	20.7	7.3	104.1	47.4
Cabot[g]	1987	2.8	1.9	27.2	39.2	20.6	279	65.1	5.7	10.2	2.4	97.3	52.9
	1986	5.6	4.1	41.9	38.4	16.9	198	35.4	5.5	11.3	2.6	86.8	53.0
Dow Chemical	1987	9.3	6.5	39.6	55.6	49.0	252	33.0	7.4	17.9	5.0	93.2	41.1
	1986	6.7	4.3	39.7	53.5	49.4	217	49.1	8.0	16.6	5.4	90.8	42.1
Ethyl	1987	11.2	11.8	38.8	22.0	9.0	172	25.5	8.0	20.5	2.9	86.8	50.4
	1986	11.3	10.7	30.2	19.6	8.7	150	24.0	8.5	22.5	3.0	92.1	49.3
Freeport-McMoRan	1987	16.4	5.5	41.7	na	na	na	20.7	16.5	9.6	na	48.0	65.5
	1986	4.1	0.9	42.0	na	na	na	156.0	19.5	6.6	na	26.7	69.4
B. F. Goodrich	1987	3.9	3.8	25.6	25.2	18.2	181	55.8	6.6	16.0	2.4	111.8	58.5
	1986	0.5	0.6	34.4	19.1	14.3	215	289.9	5.6	16.9	2.2	140.3	58.3
W. R. Grace	1987	3.1	2.7	45.5	37.9	27.8	115	84.0	5.4	14.3	2.4	100.9	47.4
	1986	1.2	0.9	45.6	32.3	16.9	90	263.0	5.3	12.6	2.5	90.9	48.3
Hercules	1987	9.9	6.8	18.2	21.3	12.0	116	36.8	7.6	19.1	2.7	77.1	49.9
	1986	8.7	6.8	24.3	21.1	15.4	104	41.4	9.8	22.3	2.7	89.7	51.4
International Minerals[h]	1987	0.9	0.5	40.7	13.7	13.7	127	276.7	3.8	4.9	3.6	67.3	55.7
	1986	def	def	48.1	13.2	9.7	85	def	8.0	7.5	2.8	48.5	57.7
Lubrizol	1987	8.0	6.7	8.3	55.2	35.9	210	59.3	4.1	14.1	6.1	107.9	42.2
	1986	8.0	7.1	8.4	51.6	31.8	203	59.3	4.1	14.0	5.2	111.3	45.0
Monsanto	1987	5.7	4.5	28.6	36.1	25.1	154	48.6	6.6	16.4	8.1	90.3	45.7
	1986	6.3	4.7	30.1	32.6	21.2	133	46.0	7.6	17.9	8.7	83.2	46.0
Olin	1987	4.0	2.9	35.9	7.3	7.7	137	47.4	6.0	15.8	3.2	114.5	36.2
	1986	4.4	3.0	29.7	6.1	8.6	129	45.6	7.5	17.8	3.3	110.5	37.6
PPG Industries	1987	7.3	5.7	29.7	29.2	28.9	141	34.9	8.2	15.9	4.4	103.9	56.5
	1986	6.8	5.1	32.8	25.5	27.4	128	35.3	7.6	13.4	4.3	101.0	58.2
Pennwalt	1987	4.7	3.8	31.5	28.4	29.7	127	58.6	4.8	12.7	3.9	109.7	47.7
	1986	4.7	3.9	33.6	23.5	21.1	115	68.0	4.9	12.5	4.1	111.1	50.7
Quantum Chemical	1987	5.6	5.0	41.0	na	na	na	50.6	6.0	11.2	na	99.4	67.8
	1986	3.2	1.8	37.6	na	na	na	136.1	5.9	7.3	na	59.6	71.9
Rohm & Haas	1987	8.9	7.2	19.7	41.5	30.0	183	30.3	10.1	30.4	6.4	112.7	41.6
	1986	6.7	5.4	21.7	38.7	28.4	171	39.1	8.7	27.6	6.4	112.2	39.8
Union Carbide	1987	3.4	2.1	69.7	30.9	36.4	160	84.1	7.3	11.6	2.3	87.6	50.3
	1986	2.1	1.2	75.3	28.6	33.2	124	110.8	8.4	12.0	2.4	82.5	51.2
Witco	1987	4.4	4.6	32.1	18.9	15.3	184	40.9	4.8	18.4	1.6	135.2	49.4
	1986	4.8	5.5	17.0	16.7	15.8	169	35.9	4.4	16.3	1.6	165.3	47.8
MEDIAN 1987		**5.6%**	**4.6%**	**32.1%**	**29.2%**	**25.6%**	**$160**	**47.4%**	**6.6%**	**15.9%**	**2.9%**	**99.4%**	**49.4%**
MEDIAN 1986		**5.3%**	**4.1%**	**33.6%**	**25.5%**	**21.1%**	**$129**	**45.6%**	**7.6%**	**16.3%**	**3.1%**	**90.9%**	**50.7%**

Note: Net income is from continuing operations, excluding extraordinary and nonrecurring items where possible. **a** Net income as a percentage of sales. **b** Net income as a percentage of current assets plus gross plant. **c** Consolidated sales only. **d** Foreign identifiable assets as a percentage of total assets. **e** Thousands of dollars. **f** Actual spending on construction of new facilities and purchase of new equipment and land in consolidated businesses. **g** Fiscal year ended Sept. 30. **h** Fiscal year ended June 30. **i** Fiscal year ended Nov. 30. **j** Fiscal year ended Oct. 31. **na** = not available. **def** = deficit.

									CAPITAL SPENDING[f]				
		Profit margin[a]	Return on investment[b]	Debt as % debt plus equity	% total sales abroad[c]	% total assets abroad[d]	Sales per employee[e]	Dividends as % of net income	as % of sales	as % of net plant	R&D as % of sales	Sales as % of assets	Net plant as % of gross plant
SALES LESS THAN $1 BILLION													
Betz Laboratories	1987	10.5%	11.3%	0.0%	16.8%	19.7%	$136	57.4%	6.6%	19.0%	3.7%	134.5%	52.4%
	1986	10.3	11.1	0.0	15.4	16.9	130	61.7	6.6	17.4	3.8	127.7	61.2
Chemed	1987	6.0	10.4	29.1	13.1	11.3	71	70.1	2.6	18.4	0.9	129.0	55.9
	1986	2.1	3.4	28.3	12.9	8.7	67	205.9	3.0	20.2	0.9	116.3	58.6
Crompton & Knowles	1987	5.0	7.5	14.5	17.3	23.8	182	33.9	1.5	12.4	2.0	175.7	46.8
	1986	4.2	5.8	22.2	14.4	24.6	163	50.6	1.6	12.3	2.1	158.2	49.4
Essex Chemical	1987	0.9	0.8	64.7	na	na	na	194.4	3.7	9.6	4.2	93.4	61.8
	1986	4.3	4.9	38.3	na	na	na	39.8	5.6	16.9	3.2	127.2	58.4
First Mississippi	1987	6.7	3.5	26.7	24.0	na	na	25.8	7.0	12.8	na	94.1	34.3
	1986	2.6	1.4	36.7	13.6	na	407	66.2	11.8	20.3	1.9	88.4	36.0
H. B. Fuller[i]	1987	4.3	6.7	17.0	45.4	55.8	130	14.7	4.9	23.0	2.1	181.2	61.8
	1986	3.6	5.7	21.5	42.5	53.1	117	17.5	2.5	12.2	2.0	181.5	62.0
GAF Corp.	1987	12.0	10.2	49.2	18.5	15.6	181	3.3	7.9	23.8	1.5	64.5	68.3
	1986	10.7	8.2	44.4	15.3	6.8	na	4.3	4.5	16.3	1.5	56.0	63.2
Georgia Gulf	1987	13.0	25.0	22.6	na	na	712	6.0	1.4	8.3	na	229.2	65.2
	1986	6.7	12.5	51.6	na	na	na	12.3	1.3	6.2	na	220.4	68.4
Great Lakes Chemical	1987	11.6	9.6	9.7	19.2	14.7	na	1.2	7.4	16.1	3.4	82.9	59.5
	1986	8.9	5.1	43.0	21.6	na	na	1.1	6.1	8.7	3.5	61.1	63.1
International Flavors	1987	14.3	10.3	0.0	70.3	50.4	181	46.9	4.9	16.8	6.0	85.3	55.7
	1986	13.8	10.6	0.0	67.9	49.0	163	51.6	4.3	14.3	6.3	92.3	55.8
Lawter International	1987	14.9	13.1	20.6	44.9	36.3	na	58.7	1.3	6.6	2.3	101.9	45.7
	1986	12.5	12.0	7.8	41.7	38.2	280	76.0	1.5	7.1	2.2	110.8	49.1
Liquid Air	1987	6.5	3.8	37.7	41.8	36.9	140	66.0	12.8	14.9	1.1	74.8	56.4
	1986	6.1	3.8	41.9	35.7	38.7	130	70.0	22.9	27.5	1.8	79.5	59.9
Loctite[h]	1987	9.1	9.6	5.5	54.3	57.4	107	27.0	4.6	21.9	3.6	111.3	59.1
	1986	8.7	8.6	8.1	47.3	58.3	100	31.0	3.5	16.1	3.8	109.3	58.6
Nalco Chemical	1987	9.5	9.0	13.0	26.1	21.8	166	58.8	6.8	18.8	4.2	112.7	50.1
	1986	8.7	8.4	6.7	23.9	22.3	151	73.9	8.6	22.7	4.5	125.5	51.2
Petrolite[j]	1987	4.3	3.3	1.4	31.8	32.8	na	107.6	6.8	19.4	4.3	112.2	45.0
	1986	6.3	5.3	2.9	22.8	25.1	na	74.3	9.0	28.3	4.3	121.7	44.2
Quaker Chemical	1987	7.0	8.2	6.0	40.7	31.3	153	32.7	2.5	11.3	5.7	124.7	54.5
	1986	6.6	7.7	11.5	36.3	28.9	138	35.3	4.0	17.3	5.5	130.1	57.4
Sigma-Aldrich	1987	13.7	12.8	7.3	16.8	16.1	105	16.9	6.8	21.2	na	106.9	68.7
	1986	13.4	12.4	9.5	14.9	14.7	94	17.9	14.0	41.2	na	103.3	71.9
Stepan	1987	3.8	4.1	42.6	na	na	288	21.8	8.9	26.0	3.9	167.3	49.5
	1986	2.9	3.2	38.8	na	na	274	28.0	5.5	16.7	3.6	170.0	49.1
Vista Chemical[g]	1987	8.0	8.9	53.9	6.4	na	381	2.5	3.4	7.8	na	121.8	77.0
	1986	5.5	6.1	78.1	5.0	na	367	6.3	2.9	5.8	na	113.4	83.8
MEDIAN 1987		**8.0%**	**9.0%**	**17.0%**	**25.1%**	**27.6%**	**$160**	**32.7%**	**4.9%**	**16.8%**	**3.6%**	**112.2%**	**55.9%**
MEDIAN 1986		**6.6%**	**6.1%**	**22.2%**	**22.2%**	**25.1%**	**$145**	**39.8%**	**4.5%**	**16.7%**	**3.4%**	**116.3%**	**58.6%**

Capital spending by U.S. chemical producers increased in 1987. Many producers, particularly those making commodity petrochemicals, have been utilizing virtually all their existing capacity. Despite problems in the automobile and housing industries, commodity chemicals such as propylene, vinyl chloride, and acrylonitrile are in strong demand.

Mindful of industry overbuilding in the 1970s, however, chemical producers have proceeded cautiously in expanding capacity and have committed more money to debottlenecking projects at present plants to bring on increased capacity at lower cost than in building new ones. Producers in some cases also are reopening mothballed plants in order to supply markets. Tenneco expects to reopen an idled methanol plant and Texaco plans to modernize and reactivate idle ethylene cracking capacity, for example.

For 26 chemical makers surveyed by C&EN, capital expenditures increased 7% last year. Some producers increased their spending significantly, among them Air Products, Dow Chemical, Du Pont, W. R. Grace, Hercules, PPG Industries, Quantum Chemical, and Rohm & Haas. Many also plan capital expenditure increases for 1988 because they think the weak U.S. dollar will allow them to expand their growing export volume and, at the same time, undercut demand for increasingly expensive foreign-produced chemicals in the U.S.

However, the Commerce Department reports that its broader survey of chemicals and allied products producers shows that capital spending declined 3% in 1987, although this number is subject to later revision. But Commerce's survey of 1988 spending plans by the

INDUSTRY CAPITAL SPENDING: Chemical industry plans significant increase for 1988

$ Billions	1988ᵃ	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Chemicals	$ 17.75	$ 16.37	$ 16.81	$ 16.44	$ 15.32	$ 12.96	$ 12.66	$ 13.11	$ 11.63	$ 9.81	$ 7.76
Iron and steel	5.45	4.63	3.82	4.12	3.54	3.25	3.78	3.48	3.44	3.21	2.60
Nonferrous metals	2.50	2.14	1.93	1.88	2.13	1.74	1.90	2.51	2.13	1.65	1.46
Paper	11.29	8.92	8.77	8.59	7.21	5.92	5.60	6.11	6.52	5.24	3.80
Petroleum	18.81	16.94	17.92	26.71	25.53	23.14	26.39	25.98	19.57	15.24	13.16
Rubber	3.67	3.52	3.89	3.86	3.11	2.46	2.16	2.15	2.03	2.46	2.33
Stone, clay, glass	3.45	3.36	3.14	3.40	3.09	2.77	2.90	3.41	3.98	3.99	3.15
All manufacturing	159.68	145.46	142.69	153.48	138.82	116.20	120.68	126.54	112.33	95.92	75.58

a Estimate. **Source:** Department of Commerce

Industry's backlog of unspent funds expanded in 1987

$ Billions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Chemicals	$ 7.0	$ 6.2	$ 8.0	$ 7.8	$ 7.5	$ 7.4	$ 9.4	$ 9.8	$ 8.5	$ 7.2	$ 7.4
Iron and steel	1.4	0.5	1.1	2.1	2.2	2.7	5.4	3.9	4.5	4.0	3.6
Nonferrous metals	1.7	1.6	2.3	2.5	3.2	3.2	3.7	3.7	2.9	2.7	2.9
Paper	6.3	4.4	4.3	5.9	4.0	5.1	5.1	4.0	4.2	3.2	2.6
Petroleum	15.2	16.7	26.2	24.7	22.3	22.9	29.7	26.7	16.1	14.6	15.0
Rubber	1.7	1.9	3.1	1.6	1.1	1.0	0.9	1.0	0.9	0.9	0.8
Stone, clay, glass	2.4	1.8	2.0	2.2	1.5	1.6	1.9	2.0	2.3	2.4	2.0
All manufacturing	76.8	69.7	95.0	94.4	73.7	70.8	92.7	91.9	76.7	63.4	56.5

Note: Figures are for fourth quarter of each year. **Source:** Conference Board

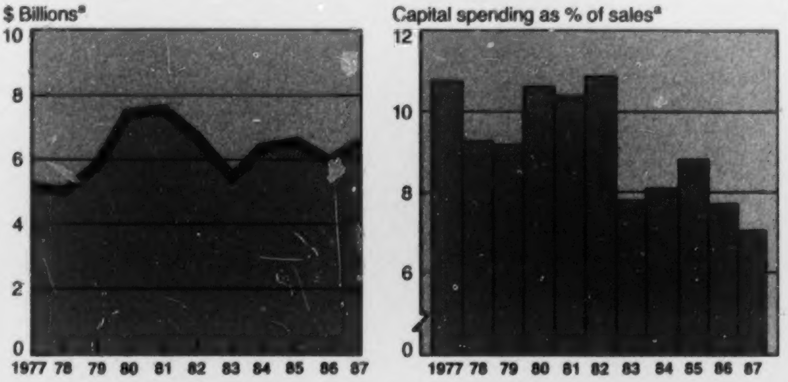
Overseas spending by chemical producers continues to grow

$ Billionsᵃ	1988ᵇ	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Chemicals and allied products	$ 3.8	$ 3.3	$ 3.1	$ 2.7	$ 2.4	$ 2.3	$ 2.8	$ 3.0	$ 3.0	$ 2.6	$ 1.9
Metals, primary and fabricated	1.0	0.8	0.9	0.9	1.0	0.9	0.9	0.8	0.9	0.6	0.6
Petroleum	12.3	10.3	9.6	13.7	14.1	15.9	19.7	15.8	14.8	11.0	9.5
All manufacturing	19.6	16.8	16.4	14.9	13.6	13.6	16.8	19.2	19.5	15.4	12.0

a By majority-owned affiliates of U.S. companies. b Planned. **Source:** Department of Commerce chemical industry indicates that its capital expenditures will rise 8% this year, the biggest year-to-year jump since 1984.

U.S. producers, meanwhile, have not concentrated on their U.S. plants to the exclusion of foreign installations. Mindful of maintaining market share in an increasingly global market, foreign affiliates of U.S. chemical companies have boosted their plant outlays steadily during the past five years. U.S. chemical companies increased capital expenditures abroad 6% in 1987 and plan an additional large increase of 15% in 1988.

Chemical capital spending increased in 1987, but continued to fall as a percentage of sales



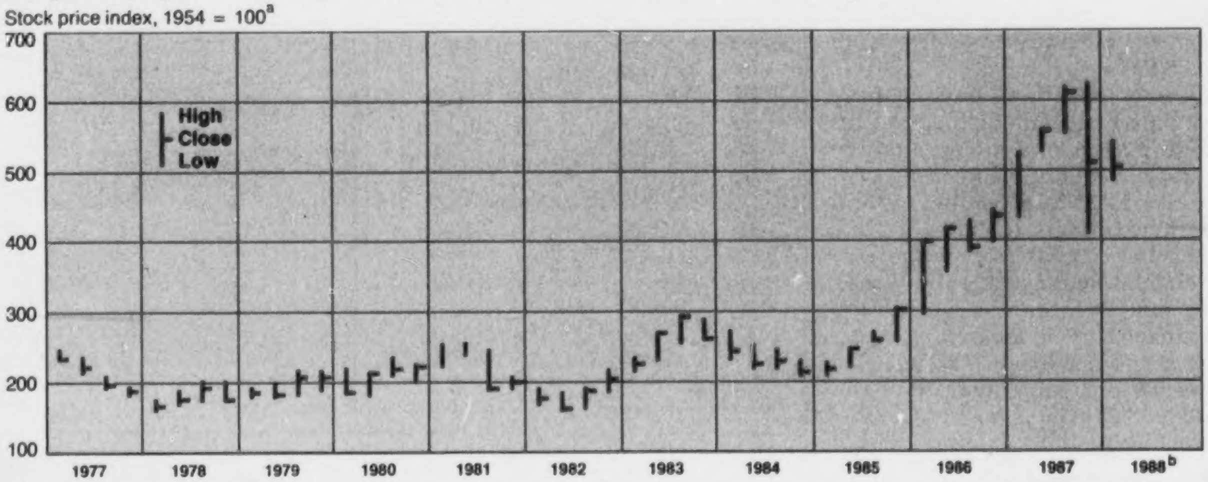
a Worldwide data for 26 major chemical producers. **Source:** Company data

CHEMICAL CAPITAL SPENDING: Bounced back in 1987 to highest level in five years

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Air Products	$ 323	$ 367	$ 392	$ 263	$ 246	$ 347	$ 323	$ 364	$ 246	$ 200	$ 143
American Cyanamid	268	263	203	200	165	171	181	196	235	251	235
Cabot[a]	83	80	184	505	80	152	194	137	98	128	51
Chemed	9	9	7	9	5	4	4	4	6	3	3
Crompton & Knowles	4	4	3	3	2	3	7	10	8	5	2
Dow Chemical	995	890	806	781	630	829	1176	1184	1268	1075	1163
Du Pont[b]	1824	1587	1515	1319	1276	1300	1420	1297	864	714	704
Essex Chemical	8	12	9	7	11	25	10	6	4	4	2
Ethyl	139	134	90	103	85	92	141	156	123	96	88
B. F. Goodrich	143	144	202	153	115	144	205	184	192	115	106
W. R. Grace	243	199	348	380	353	560	657	658	514	313	279
Great Lakes Chemical	35	18	21	29	20	29	47	21	18	9	12
Hercules	205	257	234	218	168	174	167	229	186	116	127
Loctite	15	9	11	6	10	11	13	14	9	6	4
Lubrizol	42	41	40	30	25	52	75	92	51	44	23
Monsanto	505	520	645	614	560	673	668	781	566	480	607
Nalco Chemical	57	64	60	53	41	56	59	35	39	34	33
Olin	115	128	154	165	123	129	186	172	161	163	208
Pennwalt	55	54	90	87	70	76	53	53	66	61	45
Petrolite	19	25	24	11	9	24	15	17	12	7	21
PPG Industries	426	356	452	315	450	452	376	401	252	261	212
Quantum Chemical	154	102	76	116	71	66	44	49	58	106	88
Rohm & Haas	222	179	159	124	72	126	182	93	68	66	79
Stepan	26	14	19	12	10	16	12	9	14	14	16
Union Carbide	502	524	649	670	761	1179	1186	1129	831	688	805
Witco	69	60	76	85	55	54	83	73	49	51	29
TOTAL	**$6486**	**$6040**	**$6469**	**$6258**	**$5413**	**$6744**	**$7484**	**$7364**	**$5938**	**$5010**	**$5085**
ANNUAL CHANGE	**7%**	**−7%**	**3%**	**16%**	**−20%**	**−10%**	**2%**	**24%**	**19%**	**−1%**	**−5%**

Note: Figures are for worldwide spending on construction, equipment, and land in consolidated businesses. Where possible, acquisition costs and investments in nonconsolidated businesses are excluded. a Includes acquisitions and investments. b Excludes Conoco. **Source:** Company data

Despite collapse last fall, prices of chemical stocks held well above pre-1987 level



a C&EN weighted stock price index of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide; weighted according to number of shares outstanding for each company. **b** First quarter.

SHIPMENTS: Strong recovery in industrial chemicals pushed chemicals overall to new high

$ Billions	1987[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
All manufacturing industries	$2408.6	$2273.3	$2279.1	$2254.4	$2054.9	$1960.2	$2017.5	$1852.7	$1727.2	$1523.4	$1358.4	6%	6%
Chemicals and allied products	214.6	198.3	197.3	198.2	183.2	170.7	180.5	162.5	147.7	129.8	118.2	8	6
Industrial chemicals[b]	62.7	56.4	59.6	61.5	56.6	53.2	62.7	57.3	52.3	44.8	41.5	11	4
Drugs, soap, and toiletries	72.5	69.2	60.9	57.5	54.4	50.7	46.9	41.9	36.7	34.7	30.6	5	9
Petroleum and coal products	129.7	129.3	179.1	189.0	192.6	208.9	224.1	198.7	148.4	103.9	97.5	0	3
Rubber and plastics products, nec	78.9	72.2	71.3	69.5	60.3	55.4	53.2	47.3	46.8	43.2	39.6	9	7
Paper and allied products	118.9	103.8	93.4	94.8	84.6	79.9	80.2	72.8	65.2	57.0	52.1	15	9

a Preliminary. **b** Excluding pigments. **nec** = not elsewhere classified. **Source:** Department of Commerce

PRICES: Higher for chemicals generally but industrial and ag chemicals remain depressed

Producer price indexes,[a] 1982 = 100	Annual average 1987[b]	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
All commodities	102.8	100.2	103.1	103.7	101.3	100.0	98.0	89.8	78.7	69.9	64.9	3%	5%
Industrial commodities	102.6	99.9	103.7	103.3	101.1	100.0	97.4	88.0	75.7	67.0	62.5	3	5
Chemicals and allied products	106.4	102.5	103.7	102.9	100.2	100.0	98.4	89.1	76.1	68.0	66.0	4	5
Industrial chemicals	95.5	91.5	96.0	96.8	97.3	100.0	103.0	91.9	74.9	64.0	63.5	4	4
Prepared paint	108.1	107.0	105.3	103.7	100.7	100.0	95.0	89.5	77.8	73.1	69.4	1	5
Paint materials	107.3	104.4	109.5	108.2	100.3	100.0	98.5	89.9	79.2	69.8	67.6	3	5
Drugs and pharmaceuticals	139.1	129.9	122.2	114.2	107.7	100.0	92.1	83.1	75.9	70.5	66.9	7	8
Fats and oils, inedible	92.7	80.5	110.6	139.1	106.2	100.0	110.7	111.6	141.1	118.3	104.5	15	−1
Agricultural chemicals and chemical products	96.4	94.2	96.2	97.4	96.0	100.0	97.5	87.9	73.3	67.8	64.2	2	4
Plastic resins and materials	110.3	104.4	107.5	108.9	102.4	100.0	102.0	98.5	83.2	70.5	69.1	6	5
Other chemicals and allied products	107.0	105.8	105.2	102.7	101.3	100.0	94.1	83.1	71.0	67.3	65.0	1	5
Rubber and plastics products	103.0	101.9	101.9	102.2	100.8	100.0	96.4	90.1	80.5	72.4	69.4	1	4

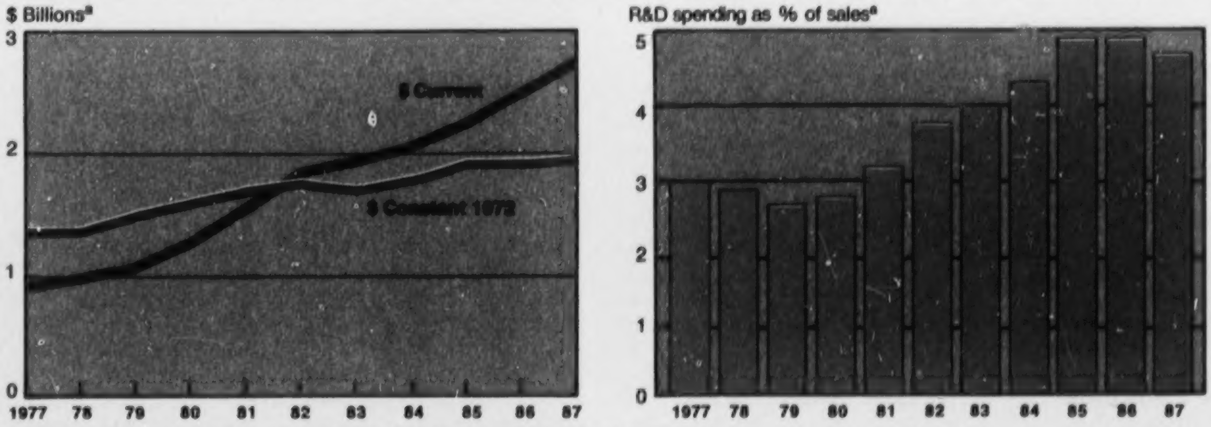
a Formerly called "wholesale price indexes." **b** Preliminary. **Source:** Department of Labor

R&D SPENDING: Most chemical producers budgeted more last year

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
CHEMICAL COMPANIES											
Air Products	$ 57	$ 61	$ 51	$ 44	$ 40	$ 37	$ 32	$ 30	$ 24	$ 23	$ 24
American Cyanamid	314	278	251	232	208	185	166	148	130	108	96
Dow Chemical	670	605	547	507	492	460	404	314	269	232	203
Ethyl	50	47	47	40	39	39	37	34	29	25	28
W. R. Grace	107	94	92	81	73	64	57	45	42	37	32
Hercules	74	71	76	72	74	74	65	57	50	43	40
International Flavors	45	39	34	32	32	31	30	29	27	24	20
Lubrizol	62	51	44	33	37	36	33	28	23	21	19
Monsanto	615	596	470	370	290	264	233	208	161	136	132
Nalco Chemical	35	33	32	32	30	33	30	28	21	17	14
Olin	62	56	53	52	49	45	38	31	26	25	25
Pennwalt	45	45	39	36	33	31	27	24	22	23	21
Petrolite	12	12	12	12	13	10	8	7	6	5	5
PPG Industries	227	204	176	150	127	127	119	103	83	70	61
Rohm & Haas	142	133	124	109	100	92	77	67	54	49	45
Union Carbide	159	148	275	265	245	240	207	166	161	156	156
TOTAL	**$2676**	**$2473**	**$2323**	**$2067**	**$1882**	**$1768**	**$1563**	**$1319**	**$1128**	**$994**	**$921**
ANNUAL CHANGE	**8%**	**6%**	**12%**	**10%**	**6%**	**13%**	**18%**	**17%**	**13%**	**8%**	**11%**
PHARMACEUTICAL & DIVERSIFIED COMPANIES											
Allied-Signal	667	734	470	389	383	177	152	105	70	56	51
Du Pont	1223	1156	1144	1097	966	879	718	591	509	461	367
Eastman Kodak	992	1059	976	838	746	710	615	520	459	389	351
Eli Lilly	466	427	370	341	294	267	235	201	178	150	127
FMC	132	146	149	121	102	105	94	81	69	54	44
Merck & Co.	566	480	426	393	356	320	274	234	188	161	145
Morton Thiokol	40	38	34	28	21	7	6	6	5	4	4
Pfizer	401	336	287	255	230	199	179	162	139	117	101
Upjohn	356	314	284	247	218	185	162	139	122	109	96
TOTAL	**$4843**	**$4690**	**$4140**	**$3709**	**$3316**	**$2849**	**$2435**	**$2039**	**$1739**	**$1501**	**$1286**
ANNUAL CHANGE	**3%**	**13%**	**12%**	**12%**	**16%**	**17%**	**19%**	**17%**	**16%**	**17%**	**7%**

Note: Prior years not restated to reflect company revisions. **Source:** Company data

Chemical R&D continued to increase last year, but fell as a percentage of company sales



[a] R&D spending by 16 major chemical producers. **Sources:** Company data, Battelle Columbus Laboratories

INDUSTRY BALANCE SHEET: Hike in current assets overshadowed by rise in liabilities

Industrial chemicals and synthetics

Assets	1987	1986	Change
	($ billions)		
Current assets			
Cash	$ 1.67	$ 2.52	−34%
Short-term securities	1.66	0.95	74
Receivables	14.66	11.69	25
Inventories	12.36	11.21	10
Other current assets	3.65	3.08	19
Total	**34.00**	**29.45**	**15**
Fixed assets			
Depreciable fixed assets	82.00	77.42	6
Land and mineral rights	3.04	2.87	6
Less: accumulated depreciation and depletion	43.80	41.51	6
Net fixed assets	**41.24**	**38.75**	**6**
Other assets, including investments and intangibles	**29.67**	**22.76**	**30**
TOTAL ASSETS	**$104.91**	**$90.99**	**15%**

Source: Bureau of the Census

Liabilities and stockholders' equity	1987	1986	Change
	($ billions)		
Current liabilities			
Short-term debt	$ 3.94	$ 3.26	21%
Accounts payable	7.58	5.76	32
Accrued income taxes	1.85	1.30	42
Current portion of long-term debt	1.47	0.85	74
Other current liabilities	9.77	8.87	10
Total	**24.61**	**20.04**	**23**
Long-term debt	**25.65**	**20.83**	**23**
Other noncurrent liabilities, including deferred taxes and minority interest	**9.73**	**8.53**	**14**
TOTAL LIABILITIES	**59.99**	**49.40**	**21**
Stockholders' equity			
Capital stock and other capital	15.59	14.87	5
Retained earnings	29.32	26.72	10
TOTAL STOCKHOLDERS' EQUITY	**44.91**	**41.59**	**8**
TOTAL LIABILITIES AND STOCKHOLDERS' EQUITY	**$104.91**	**$90.99**	**15%**

DEBT RATIOS: Climbed steadily in recent years in the chemical industry, as well as elsewhere

$ Billions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
INDUSTRIAL CHEMICALS AND SYNTHETICS											
Long-term debt	$25.7	$20.8	$19.2	$18.1	$19.4	$22.0	$21.4	$16.8	$14.8	$13.6	$12.3
Stockholders' equity	$44.9	$41.6	$40.8	$46.5	$45.3	$45.9	$42.5	$39.8	$32.3	$29.3	$26.3
Debt ratio[a]	36.4%	33.4%	32.0%	28.0%	30.0%	32.4%	33.5%	29.6%	31.4%	31.8%	31.9%
CHEMICALS AND ALLIED PRODUCTS											
Long-term debt	$51.0	$46.8	$38.2	$33.8	$36.2	$38.2	$36.9	$28.3	$24.9	$32.5	$21.1
Stockholders' equity	$106.1	$100.8	$100.3	$100.3	$97.2	$95.3	$89.9	$79.5	$67.4	$60.8	$54.9
Debt ratio[a]	32.5%	31.7%	27.6%	25.2%	27.2%	28.6%	29.1%	26.3%	27.0%	27.9%	27.8%
ALL MANUFACTURING											
Long-term debt	$449.2	$407.5	$367.0	$324.2	$286.6	$293.1	$266.5	$236.2	$204.8	$182.0	$167.3
Stockholders' equity	$912.3	$878.1	$870.7	$883.6	$837.6	$783.0	$762.3	$699.7	$624.0	$560.8	$511.7
Debt ratio[a]	33.0%	31.7%	29.6%	26.8%	25.5%	27.2%	25.9%	25.2%	24.7%	24.5%	24.6%

Note: Because of changes in accounting rules and industry classifications, numbers over the entire range of years are not strictly comparable. [a] Long-term debt as a percentage of long-term debt plus stockholders' equity. **Source:** Bureau of the Census

CASH FLOW: Profits, depreciation regained traditional status as chief sources of company funds

$ Millions, % of total	1987		1986		1985		1984		1983	
SOURCES OF FUNDS										
Net income	$ 5,697	29.6%	$ 3,414	13.6%	$ 986	6.5%	$ 3,859	29.7%	$ 2,795	23.1%
Depreciation and depletion	5,284	27.5	5,117	20.4	5,010	32.8	4,710	36.2	4,601	38.0
Deferred taxes	311	1.6	568	2.3	−34	−0.2	507	3.9	333	2.7
Other internal sources	4,272	22.2	6,084	24.3	6,707	43.9	2,357	18.1	2,623	21.7
Long-term debt	2,949	15.3	8,773	35.0	2,356	15.4	1,441	11.1	1,352	11.2
Stock	732	3.8	1,091	4.4	264	1.7	136	1.0	396	3.3
TOTAL	**$19,245**	**100.0%**	**$25,047**	**100.0%**	**$15,289**	**100.0%**	**$13,009**	**100.0%**	**$12,100**	**100.0%**
APPLICATIONS OF FUNDS										
Dividends	$ 2,181	11.3%	$ 1,992	8.0%	$ 2,049	13.4%	$ 1,998	15.4%	$ 1,868	15.4%
Capital expenditures	6,437	33.5	5,986	23.9	6,500	42.5	6,400	49.2	5,685	47.0
Additions to working capital	2,879	15.0	−567	−2.3	49	0.3	−436	−3.4	−265	−2.2
Reduction of long-term debt	2,564	13.3	7,669	30.6	2,555	16.7	2,529	19.4	3,249	26.9
Other applications	5,184	26.9	9,966	39.8	4,137	27.1	2,518	19.4	1,563	12.9
TOTAL	**$19,245**	**100.0%**	**$25,047**	**100.0%**	**$15,289**	**100.0**	**$13,009**	**100.0%**	**$12,100**	**100.0%**

Note: Data are totals for 12 major chemical producers: American Cyanamid, Dow Chemical, Du Pont, Ethyl, W. R. Grace, Hercules, Monsanto, Olin, Pennwalt, Quantum Chemical (formerly National Distillers), Rohm & Haas, and Union Carbide. **Sources:** Company annual reports

For U.S. chemical companies, 1987 was the year to draw down the dividends for the radical reorganization that many of them had undertaken two or three years earlier. The industry's austerity and restructuring programs, which reached their apex in 1985, drastically changed the organization of the industry. But the nonrecurring costs that companies charged off during the process left several corporate earnings statements severely depressed or even, temporarily and at least on paper, awash with red ink. The end result, however, was a more streamlined and much more efficient industry, one that was well-positioned to profit mightily from the steadily increasing demand for chemicals of the past few years.

This improvement is clearly evident in the financial results presented for individual companies on this and the following four pages. With only a handful of exceptions, chemical companies chalked up higher earnings last year, and in the process widened their profit margins and return on stockholders' equity.

Some of the most stunning gains were registered by companies relatively new to the industry—companies like Arco Chemical, Aristech, and Georgia Gulf—that were spun off in the past few years by parents whose prime focus was in other industries. These firms have benefited greatly, to be sure, by the remarkable recovery for commodity petrochemicals since they became independent. But they also have been the beneficiaries of more focused management and more flexible and cost-conscious corporate organizations.

Explanation of table headings

Year. Data are for calendar year unless otherwise indicated.

Net sales. Gross sales, less discounts, allowances, and returns; generally excludes excise taxes and other operating income or revenues.

Net income. Net sales and other income, less operating costs, nonoperating charges, depreciation, depletion, interest expense, deferred charges, minority interest in income, and taxes. Nonrecurring or extraordinary credits and charges have been excluded in most cases, but these items are indicated by a footnote.

Total assets. Sum at year's end of current assets, investments, prepaid expenses, net plant and equipment, and other tangible assets. Excludes insofar as possible intangible assets including goodwill, value of patents and trademarks, and the like.

Current ratio. The ratio of current assets (cash, marketable securities, receivables, and inventories but excluding prepaid expenses) to total current liabilities.

Net plant and equipment. Value at year's end of fixed assets, less accumulated depreciation, amortization, and depletion.

Capital expenditures. Total spending during the year for new fixed assets, such as plant, equipment, and land, and for replacement and modernization of facilities.

Net worth. Equity at year's end of preferred and common stock holders, including value of capital stock, capital and earned surplus, and surplus reserves, as well as contingency and miscellaneous reserves for which no definite purpose is stated. Intangible assets are deducted insofar as possible.

Net income (breakdown). **Percent of sales:** net income divided by net sales. **Percent of net worth:** net income divided by tangible net worth. **Dollars per share:** net income, less preferred dividends, divided by the number of shares of common stock outstanding. All figures are adjusted for stock splits, but no adjustment has been made for earlier years as a result of stock dividends or for dilution that might result from the conversion of preferred stock or debt to common stock or the exercise of stock options outstanding.

Dividends per share. Cash dividends paid (or declared) on each share of common stock; excludes the value of stock dividends, which are indicated by a footnote.

Dividend yield. Dividends per share divided by the average of the high and low prices of the common stock during the calendar year.

Stock price range. High-low market prices of common stock during the calendar year, adjusted for stock splits but not for stock dividends.

Price-earnings ratio. Average of the high and low prices of the common stock during the calendar year divided by net income per share.

Money figures in thousands of dollars unless otherwise indicated

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
CHEMICALS														
Air Products & Chemicals														
1987[a]	$2,132,176	$159,686[b]	$2,695,625	1.2	$1,920,520	$322,765	$1,140,512	7.5%	14.0%	$2.63[b]	$0.90	2.2%	$53⅞–29	14.6
1986[a]	1,982,134	4,735[c]	2,700,151	1.4	1,829,122	356,563	1,094,562	0.2	0.4	0.08[c]	0.77	2.2	41⅝–29⅛	442.2
1985[a]	1,829,588	143,484[d]	2,539,545	1.1	1,782,267	392,176	1,109,068	7.8	12.9	2.38[d]	0.635	2.3	34⅛–22¼	11.9
1984[a]	1,735,115	140,618	2,257,457	1.1	1,587,382	262,491	1,058,328	8.1	13.3	2.28	0.525	2.5	24¼–18¼	9.3
American Cyanamid Co.														
1987	$4,166,100	$264,000[e]	$3,878,400	1.5	$1,391,900	$258,100	$1,622,400	6.3%	16.3%	$2.89	$1.025	2.4%	$ 57–29	14.9
1986	3,815,900	202,500	3,482,400	1.7	1,267,700	262,500	1,536,000	5.3	13.2	2.18	0.95	2.6	44⅞–27⅛	16.5
1985	3,536,100	120,200[f]	3,383,400	2.0	1,126,900	202,600	1,623,000	3.4	7.4	1.25[f]	0.95	3.5	29⅝–24	21.4
1984	3,866,726	215,918	3,304,027	1.9	1,241,927	200,110	1,645,122	5.6	13.1	2.21	0.93	3.9	26½–21	10.8
Arco Chemical Co.														
1987[g]	$1,952,000	$257,000	$2,534,000	1.3	$984,000	$295,000	$1,116,000	13.2%	23.0%	$2.56[h]	$0.20	0.7%	$30⅝–17	10.8
1986	1,541,000	143,000	1,450,000	2.6	752,000	167,000	952,000[i]	9.3	15.0	1.44[h]	—	—	—	
1985	1,589,000	89,000	1,276,000	—	—	86,000	879,000[i]	5.6	10.1	—	—	—	—	
1984	1,507,000	115,000	1,252,000	—	—	—	—	7.6	—	—	—	—	—	
Aristech Chemical Corp.														
1987	$ 918,800	$ 69,700	$ 551,200	2.5	$ 299,700	$ 43,700	$ 362,700	7.6%	19.2%	$2.71	$0.54	1.9%	$ 39–16⅝	10.3
1986[j]	750,800	47,600	476,100	1.9	286,300	15,600	309,700	6.3	15.4	1.70[h]	0.00	0.0	18⅝–17⅝	10.7
1985	789,100	20,500	452,400	2.5	303,200	17,900	262,900[k]	2.6	7.8	0.65[h]	—	—	—	—
1984	862,300	42,600	465,800	—	—	9,100	270,600[k]	4.9	15.7	—	—	—	—	—

a Fiscal year ends Sept. 30. b Excludes extraordinary net loss on extinguishment of debt of $4.1 million ($0.07 per share). c Includes special charges for writedown of assets, revaluation of South African investment, and staff reduction program of $132.2 million ($2.25 per share) and for loss of investment tax credits of $7 million ($0.13 per share). d Includes special charges, before taxes, of $300,000. e From continuing operations; excludes net income from discontinued operations of $11.6 million ($0.13 per share) but includes gain on sale of fragrance and skin care businesses, before taxes, of $12.0 million ($0.13 per share). f From continuing operations; excludes net income and gain on sale of Formica Brand Products Group of $8.9 million ($0.09 per share). g Arco Chemical, previously a subsidiary of Atlantic Richfield Co., became an independent, publicly owned company on Oct. 5. h Pro forma. i Atlantic Richfield equity investment. j Aristech Chemical, previously the USS Chemicals division of USX Corp., became an independent, publicly owned company on Dec. 4. k USX Corp. equity investment.

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
(Money figures in thousands of dollars unless otherwise indicated)														
Betz Laboratories														
1987	$ 385,868	$ 40,634	$ 275,664	1.7	$ 153,200	$ 25,428	$ 193,959	10.5%	20.9%	$2.59	$1.46	3.1%	$ 58¼-35	18.0
1986	344,377	35,544	267,681	2.3	144,053	22,750	202,104	10.3	17.6	2.23	1.36	3.4	44¾-35	17.9
1985	319,381	36,792	253,704	2.2	137,255	27,030	194,793	11.5	18.9	2.33	1.26	3.7	38¼-30¼	14.7
1984	303,888	36,737	220,662	2.1	123,296	25,302	170,684	12.1	21.5	2.33	1.10	3.3	39-27¼	14.2
Cabot Corp.														
1987[a]	$ 1,424,041	$ 39,235[b]	$ 1,447,001	1.2	$ 794,470	$ 81,087	$ 574,610	2.8%	6.8%	$1.42[b]	$0.92	2.5%	$ 49¼-25¼	26.2
1986[a]	1,309,915	73,061[c]	1,490,759	2.0	642,137	72,551	572,145	5.6	12.8	$2.56[c]	0.92	3.1	35⅝-23⅜	11.5
1985[a]	1,407,516	71,290[d]	1,573,086	1.9	523,211	141,559	604,085	5.1	11.8	2.22[d]	0.92	3.4	33¾-20½	12.2
1984[a]	1,752,523	97,073	1,730,722	1.8	1,051,251	116,911	699,167	5.5	13.9	3.02	0.92	3.6	28⅞-22⅝	8.5
Chemed Corp.														
1987	$ 391,004	$ 20,362	$ 220,549	1.5	$ 48,545	$ 8,893	$ 69,944	5.2%	29.1%	$2.28	$1.60	4.5%	$ 44⅛-26⅝	15.5
1986	359,476	6,830[e]	229,316	1.6	46,554	9,385	75,330	1.9	9.1	0.76[e]	1.56	4.4	40-30⅛	46.1
1985	372,677	21,858	197,615	1.7	42,092	7,874	58,234	6.6	37.5	2.49	1.52	5.1	33⅝-25¾	11.9
1984	346,140	20,110	180,518	1.7	45,517	9,198	49,822	5.8	40.4	2.20	1.48	4.7	36⅝-25¾	13.6
Crompton & Knowles Corp.														
1987	$ 237,469	$ 11,750	$ 127,689	2.2	$ 29,085	$ 3,632	$ 68,265	4.9%	17.2%	$1.95	$0.67	2.8%	$ 30¼-18	12.4
1986	213,242	8,923[f]	126,881	2.2	28,511	3,514	60,565	4.2	14.5	1.32[f]	0.63	4.0	19⅝-12⅛	12.0
1985	231,225	7,575	120,076	2.5	30,376	3,362	63,830	3.3	11.9	1.10	0.60	5.3	13⅝-9¼	10.3
1984	230,434	7,891	114,135	2.5	30,809	3,917	59,586	3.4	13.2	1.15	0.57	5.3	11⅞-9⅝	9.3
Dow Chemical Co.														
1987	$13,377,000	$1,245,000[g]	$13,871,000	1.7	$ 5,551,000	$ 995,000	$ 5,284,000	9.3%	23.6%	$6.50[g]	$2.10	2.5%	$109⅝-58¾	13.0
1986	11,113,000	741,000[h]	11,939,000	1.6	5,347,000	890,000	4,865,000	6.7	15.2	3.87[h]	1.85	3.6	61¾-39⅞	13.1
1985	10,500,000	58,000	11,565,000	1.5	5,127,000	806,000	4,527,000	0.6	1.3	0.31	1.80	5.2	41⅞-27	111.1
1984	10,679,000	549,000[i]	11,217,000	1.5	5,173,000	781,000	4,860,000	5.1	11.3	2.83[i]	1.80	6.0	34½-25¾	10.6
E. I. du Pont de Nemours & Co.														
1987	$30,468,300	$1,786,000	$27,603,000	1.5	$15,854,000	$3,035,000	$13,639,000	5.9%	13.1%	$7.39	$3.30	3.2%	$ 131-75	13.9
1986	27,148,000	1,538,000	26,083,000	1.5	15,697,000	2,737,000	12,724,000	5.7	12.1	6.35	3.05	4.0	92½-59½	12.0
1985	29,483,000	1,118,000	25,108,000	1.6	15,195,000	3,046,000	12,627,000	3.8	8.9	4.61	3.00	5.1	69⅝-47⅝	12.7
1984	35,915,000	1,431,000	24,098,000	1.6	14,409,000	2,931,000	12,233,000	4.0	11.7	5.93	2.90	6.1	52⅞-42⅜	8.0
Essex Chemical Corp.														
1987	$ 208,766	$ (2,748)[j,k]	$ 207,058	1.0	$ 81,002	$ 7,895	$ 26,065	—	—	$(0.35)[j,k]	$0.49	2.4%	$ 28-12¾	—
1986	205,624	8,836	159,499	1.3	68,830	11,614	57,336	4.3%	15.4%	1.15	0.46	2.5	23⅝-12⅞	15.8
1985	190,049	8,502	140,195	2.1	64,161	8,788	50,617	4.5	16.8	1.12	0.42	3.3	15⅝-9¾	11.3
1984	175,833	9,092[l]	135,654	2.2	62,469	6,848	44,885	5.2	20.3	1.20[l]	0.38	3.5	13¼-8¾	8.8
Ethyl Corp.														
1987	$ 1,720,338	$ 193,315	$ 1,875,614	2.2	$ 674,075	$ 138,481	$ 852,799	11.2%	22.7%	$1.57	$0.40	1.7%	$ 32¼-15	15.0
1986	1,579,254	177,734	1,667,825	2.1	594,238	133,700	895,790	11.3	19.8	1.40	0.335	1.8	22¾-13½	12.9
1985	1,547,034	117,146[m]	1,509,988	2.0	557,256	89,512	754,853	7.6	15.5	0.92	0.285	2.5	15¼-7⅞	12.6
1984	1,675,059	132,184[n]	1,437,207	2.2	573,156	103,416	707,716	7.9	18.7	0.86	0.21	3.2	8¼-5	7.7
Ferro Corp.														
1987	$ 871,088	$ 31,687	$ 521,314	1.7	$ 171,889	$ 30,674	$ 240,039	3.6%	12.7%	$2.30	$0.67	2.7%	$ 31¼-17½	10.6
1986	725,241	24,082	443,801	1.9	153,712	23,162	217,750	3.3	11.1	1.77	0.60	3.4	20⅝-15⅛	10.1
1985	651,071	11,163[o]	391,133	2.0	145,651	26,451	193,850	1.7	5.6	0.83[o]	0.60	3.9	18½-12⅛	18.4
1984	662,867	16,886	350,938	2.0	136,462	29,364	185,983	2.5	9.1	1.27	0.60	4.0	19¼-11⅛	12.0
First Mississippi Corp.														
1987[p]	$ 278,946	$ 18,610	$ 276,638	1.8	$ 152,671	$ 19,527	$ 138,882	6.7%	13.4%	$0.93	$0.24	1.9%	$ 19⅛-6½	13.8
1986[p]	268,898	(28,110)[j]	287,562	1.6	155,206	31,635	125,521	—	—	(1.42)[j]	0.24	3.6	8⅛-5⅛	—
1985[p]	273,185	18,239[q]	379,587	1.5	234,574	63,257	165,339	6.7	10.1	0.90[q]	0.24	2.6	11⅝-6⅝	10.1
1984[p]	270,004	15,845[r]	380,855	1.5	209,742	41,034	166,957	5.9	9.5	0.77[r]	0.24	2.3	13¾-7¼	13.6
GAF Corp.														
1987	$ 836,928	$ 100,052[s]	$ 1,241,482	2.6	$ 276,620	$ 65,911	$ 452,028	12.0%	22.1%	$2.53[s]	$0.10	0.2%	$ 69½-31¾	17.3
1986	753,774	80,686[t]	1,341,325	3.9	208,396	33,914	595,754	10.7	13.5	2.22[t]	0.10	0.3	44-23⅞	15.3
1985	731,962	54,296[u]	870,174	1.7	194,086	47,161	298,153	7.4	18.2	1.57[u]	0.10	0.4	35-12⅛	15.0
1984	731,314	41,406[v]	452,273	2.2	159,115	17,900	214,006	5.7	19.3	1.31[v]	0.05	0.5	12⅞-7½	7.8

[a] Fiscal year ends Sept. 30. [b] Excludes extraordinary net charge on early retirement of indebtedness of $10.5 million ($0.38 per share). [c] Excludes extraordinary charge on early retirement of indebtedness of $2.0 million ($0.07 per share). [d] From continuing operations; excludes net loss from discontinued operations of $12.7 million ($0.39 per share) and provision for net loss on disposal of discontinued operations of $145.0 million ($4.53 per share). [e] From continuing operations; excludes net income and gain on sale of discontinued Vestal Laboratories operations of $30.0 million ($3.36 per share) and extraordinary gain on termination of pension plan of $811,000 ($0.09 per share). [f] From continuing operations; excludes net income and charge for discontinued Kem operations of $7.9 million ($1.24 per share). [g] Excludes net loss on early extinguishment of debt of $5 million ($0.03 per share). [h] Excludes net loss on early extinguishment of debt of $9 million ($0.05 per share). [i] Includes pretax gain on sales of investments of $183 million but excludes tax benefit from realization of foreign tax loss carry-forwards of $36 million ($0.19 per share). [j] Net loss. [k] From continuing operations; excludes net loss on discontinued operations of $13.3 million ($1.73 per share) and extraordinary loss on early retirement of debt of $556,000 ($0.07 per share). [l] From continuing operations; excludes net loss from discontinued coated products operations of $2.0 million ($0.26 per share). [m] Includes net charge for plant shutdown and write-off costs of $20.0 million. [n] Includes net nonrecurring charges of $25.2 million. [o] Excludes net loss on sale of Productol Chemical Division of $2.3 million ($0.17 per share). [p] Fiscal year ends June 30. [q] Excludes net gain from disposal of FirstMiss subsidiary of $900,000 ($0.04 per share). [r] Excludes net gain from disposal of FirstMiss subsidiary of $120,000 ($0.01 per share). [s] Excludes extraordinary credits of $137.5 million ($4.03 per share). [t] Excludes extraordinary credits of $212.5 million ($5.86 per share). [u] Excludes extraordinary credits of $23.3 million ($0.68 per share). [v] Excludes extraordinary credits of $15.7 million ($0.54 per share).

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME			Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
								% of sales	% of net worth	$ per share				
(Money figures in thousands of dollars unless otherwise indicated)														
Georgia Gulf Corp.														
1987	$ 707,453	$ 91,736[a]	$ 308,609	1.7	$ 119,984	$ 9,931	$ 142,546	13.0%	64.4%	$ 6.29[a]	$0.40	0.9%	$ 69–19¾	7.1
1986	583,255	39,123	264,632	2.0	110,116	7,428	77,956	6.7	50.2	2.41	0.00	0.0	20–19½	8.2
1985	613,537	36,431	292,142	1.1	135,007	6,177	36,289	5.9	100.4	2.21	0.00	—	—	—
1984[b]	610,345	19,494	506,735	—	—	—	—	3.2	—	—	—	—	—	—
B. F. Goodrich Co.														
1987	$2,186,000	$ 83,900[c]	$1,905,800	1.4	$ 898,200	$142,600	$ 972,600	3.9%	8.6%	$ 3.17[c]	$1.56	3.4%	$ 65–27¾	14.6
1986	2,553,300	12,900[d]	1,786,700	1.4	865,200	144,000	799,200	0.5	1.6	0.46[d]	1.56	3.9	47⅞–32⅛	87.0
1985	3,200,500	(316,800)[e,f]	2,227,400	1.1	1,043,900	202,300	675,800	—	—	(14.11)[e,f]	1.56	5.0	35–25¾	—
1984	3,340,800	60,600	2,544,000	1.5	1,307,400	153,200	1,065,800	1.8	5.7	2.52	1.56	5.1	36⅝–24⅝	12.1
W. R. Grace & Co.														
1987	$4,515,400	$141,900[g]	$4,361,500	1.4	$1,701,000	$242,500	$1,351,200	3.1%	10.5%	$ 1.67[g]	$1.40	5.0%	$ 37⅝–19⅛	16.9
1986	3,725,700	(375,400)[e,h]	3,993,000	1.3	1,579,000	199,100	1,204,400	—	—	(4.47)[e,h]	1.40	5.3	30⅝–22⅝	—
1985	5,193,000	127,800[i]	5,287,800	1.9	2,596,000	348,000	2,271,400	2.5	5.6	1.22[i]	1.40	6.6	24¾–17¾	17.3
1984	6,727,800	195,600	5,193,900	1.6	2,704,200	380,100	2,063,300	2.9	9.5	2.01	1.40	6.7	23½–18⅛	10.4
Great Lakes Chemical Corp.														
1987	$ 478,386	$ 55,536	$ 523,365	1.8	$ 218,403	$ 35,186	$ 338,880	11.6%	16.4%	$ 3.34	$0.60	1.1%	$ 77–35⅞	16.9
1986	300,329	26,817	447,840	2.3	209,425	18,327	172,538	8.9	15.5	1.79	0.52	1.4	44½–30⅞	21.1
1985	276,932	28,818	314,423	2.2	137,710	21,344	186,718	10.4	15.4	1.93	0.44	1.2	44¼–31⅛	19.6
1984	278,235	35,568	276,469	2.2	130,784	28,770	164,805	12.8	21.6	2.38	0.36	1.1	38⅝–24	13.2
Hercules														
1987	$2,693,003	$208,000[j]	$3,492,077	3.6	$1,075,389	$205,037	$2,189,867	7.7%	9.5%	$ 4.02[j]	$1.84	3.2%	$ 73½–40	14.1
1986	2,615,110	206,200[k]	2,914,319	2.6	1,152,141	256,913	1,703,151	7.8	12.1	3.66[k]	1.72	3.5	60–37	13.3
1985	2,587,213	133,161[l]	2,658,822	2.5	1,000,212	234,240	1,474,201	5.1	9.0	2.40	1.60	4.5	40¾–31⅛	15.0
1984	2,570,965	197,185	2,388,489	2.4	906,031	218,105	1,366,911	7.7	14.4	3.54	1.48	4.5	38–27¼	9.2
International Flavors & Fragrances														
1987	$ 745,861	$107,017	$ 674,554	4.2	$ 219,305	$ 36,946	$ 659,908	14.3%	16.2%	$ 2.85	$1.24	2.6%	$ 57¾–37⅛	16.8
1986	620,679	85,683	672,616	4.6	186,891	26,771	521,475	13.8	16.4	2.29	1.16	2.8	48⅞–34½	18.2
1985	501,046	69,698	559,855	4.2	159,298	22,134	426,986	13.9	16.3	1.89	1.12	3.4	40–26	17.5
1984	476,678	69,242	452,392	4.4	140,109	20,942	351,183	14.5	19.7	1.89	1.08	4.1	29¼–22⅞	13.8
International Minerals & Chemical Corp.														
1987[m]	$1,037,500	$ 14,600[n]	$2,242,400	1.4	$2,292,500	$ 62,500	$ 877,200	0.9%	1.7%	$ 0.08[n]	$1.00	2.5%	$ 53–26½	496.9
1986[m]	1,177,700	(79,600)[e,o]	2,225,200	2.2	2,170,700	93,900	792,400	—	—	(2.96)[e,o]	1.80	5.9	36¼–25	—
1985[m]	1,627,300	119,600	1,957,200	2.0	2,144,300	116,000	1,092,000	7.3	11.0%	4.39	2.60	6.6	44–34¼	8.9
1984[m]	1,532,900	112,000[p]	1,965,600	1.9	2,061,400	104,800	1,039,100	7.3	10.8	4.17[p]	2.60	6.4	49–32⅞	9.8
Lawter International														
1987	$ 112,018	$ 16,701	$ 109,917	4.3	$ 22,603	$ 1,528	$ 69,458	14.9%	24.0%	$ 0.71	$0.42	3.5%	$ 15⅝–8½	17.0
1986	103,515	12,945	93,392	3.7	22,447	1,613	55,191	12.5	23.5	0.56	0.42	3.9	13–8⅝	19.5
1985	96,769	(5,413)[e,q]	84,039	3.4	22,702	3,179	47,588	—	—	(0.23)[e,q]	0.42	4.7	10⅛–7¾	—
1984	98,404	14,862	77,877	4.8	21,146	3,339	58,370	15.1	25.5	0.65	0.41	4.4	10⅞–7⅛	14.5
Liquid Air Corp.														
1987	$ 562,243	$ 36,822[r]	$ 718,809	1.2	$ 485,095	$ 72,173	$ 325,196	6.5%	11.3%	$ 2.59[r]	$1.60	5.7%	$ 36½–19½	10.8
1986	570,565	34,680	682,307	1.1	475,321	130,544	303,554	6.1	11.4	2.42	1.60	5.1	36½–25¾	12.9
1985	543,041	31,753	599,281	1.2	418,165	103,675	289,819	5.8	11.0	2.42	1.60	6.8	27¾–19½	9.8
1984	501,735	27,304	549,821	1.8	370,530	62,461	246,667	5.4	11.1	2.07	1.60	7.7	23–18⅛	10.0
Loctite Corp.														
1987[m]	$ 337,802	$ 30,665	$ 299,367	1.9	$ 70,802	$ 15,470	$ 167,561	9.1%	18.3%	$ 1.69	$0.47	1.7%	$ 36–19	16.3
1986[m]	266,788	23,173	240,665	2.2	$ 57,711	9,299	150,163	8.7	15.4	1.28	0.41	2.0	24⅞–16⅝	16.2
1985[m]	231,479	20,443	215,482	1.9	49,793	11,278	121,918	8.8	16.8	1.12	0.40	2.5	18½–13½	14.3
1984[m]	241,744	26,349	223,694	2.0	45,696	6,172	129,526	10.9	20.3	1.33	0.32	1.7	21⅜–15¼	13.7
Lubrizol Corp.														
1987	$1,013,430	$ 81,335	$ 939,378	3.0	$ 297,573	$ 42,040	$ 621,633	8.0%	13.1%	$ 2.06	$1.22	3.6%	$ 41⅜–25¼	16.3
1986	976,776	78,185	877,907	2.7	289,078	40,460	572,679	8.0	13.7	1.97	1.17	3.9	35⅛–25⅝	15.4
1985	903,403	60,224	854,445	2.4	290,298	39,498	519,298	6.7	11.6	1.49	1.16	4.8	28⅞–19¾	16.3
1984	831,681	67,731	701,974	2.8	251,735	29,490	474,343	8.1	14.3	1.73	1.12	5.2	24½–18⅛	12.4
Monsanto Co.														
1987	$7,639,000	$436,000	$6,502,000	1.4	$3,076,000	$505,000	$1,948,000	5.7%	22.4%	$ 5.63	$2.75	3.5%	$100¼–57	14.0
1986	6,879,000	433,000	6,125,000	1.4	2,913,000	520,000	1,637,000	6.3	26.5	5.55	2.575	4.1	81½–44¾	11.4
1985	6,747,000	(128,000)[e,s]	6,678,000	1.1	3,034,000	645,000	1,208,000	—	—	(1.67)[e,s]	2.45	5.1	55⅝–40⅝	—
1984	6,691,000	439,000	6,250,000	2.0	3,374,000	614,000	3,511,000	6.6	12.5	5.42	2.25	4.8	53⅞–40⅝	11.5

a Excludes extraordinary net charge on early retirement of debt of $9.9 million ($0.68 per share). b Georgia Gulf became an independent corporation on Dec. 31, 1984, when it acquired a major portion of the assets of the chemical division of Georgia-Pacific Corp.; data for 1984 are for the latter. c From continuing operations; excludes net loss from discontinued operations of $4.7 million ($0.20 per share) and extraordinary net income of $25.8 million ($1.09 per share). d Excludes extraordinary net income of $19.8 million ($0.86 per share). e Net loss. f From continuing operations; excludes net loss from discontinued operations of $37.8 million ($1.68 per share). g From continuing operations; excludes net income from discontinued operations of $18.6 million ($0.22 per share) and tax benefit of operating loss carry-forward of $12.6 million ($0.14 per share). h From continuing operations; includes asset write-downs and reserves, before taxes, of $368.8 million but excludes net loss from discontinued operations of $96.9 million ($1.15 per share). i From continuing operations; excludes net income from discontinued retail operations of $19.1 million ($0.18 per share). j Excludes net gain on disposal of Himont and other net gains and charges of $613.7 million ($10.72 per share). k Excludes nonrecurring net gains from sale of investments and businesses and nonrecurring net costs of $20.5 million ($0.36 per share). l Includes pretax gain on disposal of assets of $16.4 million. m Fiscal year ends June 30. n From continuing operations; excludes net income on disposal of discontinued operations of $11.3 million ($0.41 per share) and extraordinary net charge of $4.8 million ($0.18 per share). o From continuing operations; excludes net loss from and net provision for loss on disposal of discontinued gas and oil and industrial products operations of $137.4 million ($5.08 per share). p Excludes net loss from operation and disposal of discontinued methanol joint venture of $30.3 million ($1.13 per share). q Includes one-time tax provision for future repatriation of foreign earnings of $14.0 million ($0.60 per share). r From continuing operations; excludes net loss from discontinued diving equipment operations of $224,000 ($0.02 per share). s Includes special charge for restructuring costs, before taxes, of $557 million but excludes net gain from repayment of debt of $30 million ($0.40 per share).

								NET INCOME						
Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	% of sales	% of net worth	$ per share	Dividends, $ per share	Dividend yield, % of price	Stock price range, $ per share	Price-earnings ratio
(Money figures in thousands of dollars unless otherwise indicated)														
Morton Thiokol														
1987[a]	$1,987,300	$138,000	$ 1,426,400	1.5	$ 655,900	$130,400	$ 700,400	6.9%	19.7%	$2.90	$0.745	1.7%	$54¾–31	14.8
1986[a]	1,949,900	132,900	1,225,000	1.7	593,900	95,700	629,900	6.8	21.1	2.80	0.685	1.9	42½–30	12.9
1985[a]	1,832,300	119,500[b]	1,173,900	1.8	560,700	117,000	510,500	6.5	23.4	2.44[b]	0.63	1.9	40½–26	13.6
1984[a]	2,001,508	109,759	1,152,082	1.5	526,713	90,859	489,545	5.5	22.4	2.17	0.57	2.2	31½–20	11.9
Nalco Chemical Co.														
1987	$ 841,876	$ 80,254	$ 696,360	1.7	$ 304,084	$ 57,232	$ 396,297	9.5%	20.3%	$2.03	$1.20	3.5%	$45½–24	17.1
1986	736,074	63,672	536,916	1.7	280,195	63,636	358,023	8.7	17.8	1.62	1.20	4.4	31⅛–23½	16.9
1985	682,333	73,332	492,998	1.8	247,912	59,905	335,685	10.7	21.8	1.87	1.20	4.8	28⅜–22	13.5
1984	664,303	73,086[c]	471,543	2.4	205,103	52,478	344,302	11.0	21.2	1.86[c]	1.20	4.4	33¼–21	14.6
Olin Corp.														
1987	$1,930,000	$ 78,000	$ 1,583,000	1.7	$ 727,000	$115,000	$ 598,000	4.0%	13.0%	$3.38	$1.60	3.6%	$56¼–32⅝	13.1
1986	1,707,261	75,226	1,464,830	1.5	719,686	127,935	574,290	4.4	13.1	3.36	1.525	3.5	53¼–34⅝	13.1
1985	1,751,106	(190,308)[d,e]	1,516,096	1.6	718,371	154,499	604,844	—	—	(8.28)[d,e]	1.50	4.5	38–28⅝	—
1984	2,065,328	88,747	1,822,099	1.9	860,658	165,000	867,307	4.3	10.2	3.81	1.365	4.7	33½–25⅛	7.7
Pennwalt Corp.														
1987	$1,142,750	$ 53,803[f]	$ 993,626	1.9	$ 432,029	$ 54,877	$ 427,110	4.7%	12.6%	$4.12	$2.25	4.4%	$68¼–34¾	12.5
1986	1,107,564	51,947	962,252	2.1	436,282	54,379	465,369	4.7	11.2	3.64	2.20	4.4	59–40⅝	13.7
1985	1,013,308	11,216[g]	937,672	1.5	433,867	89,691	445,020	1.1	2.5	0.05[g]	2.20	5.6	44½–34	785.0
1984	1,047,214	45,356	868,673	1.9	393,765	87,177	485,325	4.3	9.3	3.31	2.20	6.0	42¼–31½	11.1
Quantum Chemical Corp.														
1987	$2,566,800	$143,600[h]	$ 2,519,300	1.3	$1,380,200	$154,200	$ 983,500	5.6%	14.6%	$4.38[h]	$2.20	3.4%	$ 88–42½	14.9
1986	1,729,600	55,100[i]	2,844,200	1.0	1,393,800	101,600	944,500	3.2	5.8	1.54[i]	2.20	5.7	47⅝–30	25.3
1985	2,289,000	77,000[i]	1,948,000	1.5	899,300	76,200	930,300	3.4	8.3	2.27[i]	2.20	7.2	37½–23⅝	13.5
1984	2,244,900	69,900[k]	1,828,800	1.9	747,700	116,100	943,500	3.1	7.4	2.01[k]	2.20	8.3	30–22¾	13.1
Rohm & Haas Co.														
1987	$2,203,000	$195,000[j]	$ 1,882,000	1.9	$ 730,000	$222,000	$ 981,000	8.9%	19.9%	$2.85[j]	$0.86	2.2%	$53¼–24	13.6
1986	2,067,000	138,000[m]	1,756,000	2.9	648,000	179,000	916,000	6.7	15.1	2.01[m]	0.78	2.5	38⅜–23⅞	15.6
1985	2,051,000	141,000[n]	1,655,000	2.0	581,000	159,000	857,000	6.9	16.5	2.01[n]	0.70	3.1	26⅛–18⅝	11.1
1984	2,042,011	172,219[o]	1,540,570	2.0	555,945	134,253	872,687	8.4	19.7	2.24[o]	0.60	3.1	23⅛–16	8.7
Sigma-Aldrich Corp.														
1987	$ 304,858	$ 41,889	$ 285,343	2.9	$ 96,975	$ 20,616	$ 196,012	13.7%	21.4%	$1.70	$0.29	0.7%	$50⅝–30¼	23.8
1986	253,097	33,958	244,875	2.5	86,111	35,461	155,689	13.4	21.8	1.38	0.25	0.7	40¼–26¾	24.3
1985	214,848	28,855	186,552	3.4	57,771	17,388	126,306	13.4	22.9	1.13	0.21	0.9	28⅜–17⅛	20.1
1984	179,529	24,220	174,144	5.4	46,037	11,852	129,932	13.5	18.6	0.93	0.175	1.1	17⅛–14⅜	16.9
Stepan Co.														
1987	$ 288,935	$ 10,959	$ 172,726	1.6	$ 98,994	$ 25,705	$ 59,936	3.8%	18.3%	$3.67	$0.83	2.0%	$53½–29	11.2
1986	259,787	7,513	152,794	1.5	85,607	14,322	55,029	2.9	13.6	2.53	0.74	2.6	35⅝–20¾	11.3
1985	235,919	5,471	139,307	1.5	82,796	19,189	49,575	2.3	11.0	1.89	0.69	3.5	23¼–16⅝	10.5
1984	234,930	5,423[p]	133,941	1.6	73,261	11,557	47,660	2.3	11.4	1.66[p]	0.65	3.9	18⅝–14½	10.0
Union Carbide Corp.														
1987	$6,914,000	$232,000	$ 7,820,000	1.3	$4,344,000	$502,000	$1,175,000	3.4%	19.7%	$1.76	$1.50	6.2%	$32½–15½	13.6
1986	6,244,000	130,000[q]	7,496,000	1.2	4,379,000	524,000	930,000	2.1	14.0	1.25[q]	1.50	5.8	33⅛–18¾	20.8
1985[r]	6,596,000	(38,000)[d]	8,461,000	1.3	4,927,000	649,000	519,000	—	—	(0.38)[d]	1.13	6.1	24¾–12	—
1984	9,508,000	341,000[s]	10,402,000	1.8	6,383,000	670,000	4,808,000	3.6	7.1	1.61[s]	1.13	6.9	21¾–10⅞	10.1
Vista Chemical Corp.														
1987[t]	$ 608,887	$ (1,762)[u]	$ 474,265	1.5	$ 266,250	$ 20,889	$ 134,686	—	—	($0.13)[u]	$0.05	0.1%	$55⅛–18⅝	—
1986[t]	550,097	30,212[v]	453,418	1.8	272,699	15,792	60,808	5.5%	49.7%	1.73[v]	0.00	0.0	18¾–17	10.3
1985[t]	521,313	11,917	454,688	1.9	282,946	10,284	23,281	2.3	51.2	0.68	0.00	0.0	—	—
1984[t,w]	101,122	2,006	536,102	—	—	1,596	—	2.0	—	0.12	0.00	0.0	—	—
Witco Corp.														
1987	$1,427,650	$ 63,293	$ 1,037,624	3.0	$ 374,628	$ 69,082	$ 494,941	4.4%	12.8%	$2.72	$1.16	3.1%	$47⅝–26⅝	13.6
1986	1,355,018	65,215	804,086	2.4	367,789	60,102	449,783	4.8	14.5	2.93	1.05	3.2	40–26⅝	11.3
1985	1,448,929	56,774	794,368	2.3	360,950	71,093	399,486	3.9	14.2	2.57	0.99	4.0	27¾–22	9.7
1984	1,495,831	62,602	739,488	2.2	348,740	65,720	358,497	4.2	17.5	2.85	0.93	4.2	26⅝–18⅜	7.8

a Fiscal year ends June 30. b From continuing operations; excludes net income from discontinued Texsize Division operations of $3.3 million ($0.06 per share) and net gain on sale of the division of $75.1 million ($1.51 per share). c Excludes net income from discontinued lead antiknock compounds operations of $3.1 million ($0.08 per share). d Net loss. e From continuing operations; includes special charge for restructuring costs, before taxes, of $330.0 million but excludes net income and net gain on sale of Ecusta paper and film businesses of $25.0 million ($1.09 per share). f From continuing operations; excludes net income from discontinued equipment operations of $1.4 million ($0.10 per share). g From continuing operations; includes special charge for restructuring program, before taxes, of $38.6 million but excludes net loss from operations and on disposal of discontinued dental businesses of $30.9 million ($2.80 per share). h From continuing operations; excludes net income from discontinued spirits and wine operations of $108.0 million ($3.37 per share). i From continuing operations; excludes net income from discontinued spirits and wine operations of $20.5 million ($0.67 per share). j From continuing operations; excludes net income from discontinued insurance business of $200,000 ($0.01 per share). k From continuing operations; excludes net loss from discontinued metals and petroleum operations of $18.5 million ($0.60 per share). l Includes net gain on sales of assets of $5.0 million ($0.07 per share). m Includes net loss on disposal of assets of $9.2 million ($0.13 per share). n Includes net gain on disposal of assets of $4.6 million ($0.07 per share). o Includes net loss on sale of oil and gas properties of $3.6 million ($0.05 per share). p Includes nonrecurring net loss on write-down of equipment of $2.6 million. q From continuing operations; excludes net income and net gain on disposal of discontinued operations of $569 million ($5.49 per share) and net charges for extraordinary items of $203 million ($1.96 per share). r Pro forma, after adjustment for repurchase of common stock, sale of consumer products businesses, special charges for restructuring program, and other special gains and losses. s Excludes extraordinary charge related to accident in Bhopal, India, of $18 million ($0.08 per share). t Fiscal year ends Sept. 30. u Includes net charge associated with change in stock option plan of $55.4 million and net gain on sale of interest in Petroquimica Argentina of $5.1 million but excludes net loss on extinguishment of debt of $1.9 million ($0.12 per share). v From start of operations July 20. w From continuing operations; excludes net income from operations and net gain on sale of discontinued businesses of $76.3 million ($0.50 per share).

(Money figures in thousands of dollars unless otherwise indicated)

Year	Net sales	Net income	Total assets	Current ratio	Net plant and equipment	Capital expenditures	Net worth	NET INCOME % of sales	NET INCOME % of net worth	NET INCOME $ per share	Dividends, $ per share	Dividend yield, % of price	Stock-price range, $ per share	Price-earnings ratio
PHARMACEUTICALS														
Abbott Laboratories														
1987	$4,387,876	$632,559	$4,385,737	1.3	$1,741,557	$432,700	$2,093,453	14.4%	30.2%	$2.78	$1.00	1.9%	$ 67–40	19.3
1986	3,807,634	540,460	3,865,609	1.3	1,543,267	383,400	1,778,921	14.2	30.4	2.32	0.84	1.9	55–31⅝	18.7
1985	3,360,273	465,335	3,468,373	1.9	1,368,542	292,900	1,870,663	13.8	24.9	1.94	0.70	2.5	36–19⅞	14.4
1984	3,103,962	402,575	3,172,897	1.7	1,236,572	334,800	1,602,700	13.0	25.1	1.67	0.60	2.8	24⅜–18⅜	12.8
American Home Products Corp.														
1987	$5,028,272	$845,081	$3,956,855	2.0	$1,153,028	$278,525	$1,878,178	16.8%	45.0%	$5.73	$3.34	4.2%	$ 96¾–62	13.9
1986	4,926,512	778,824[a]	3,819,146	2.7	929,400	204,764	2,024,869	15.8	38.5	5.18[a]	3.10	4.0	94⅞–61⅛	15.1
1985	4,684,742	717,140	3,201,746	3.3	859,414	179,347	2,098,293	15.3	34.2	4.70	2.90	5.0	66⅞–50⅛	12.4
1984	4,485,470	655,828[b]	2,849,732	3.3	769,623	141,891	1,905,733	14.6	34.4	4.26[b]	2.64	5.2	55¾–46⅜	12.0
Bristol-Myers Co.														
1987	$5,401,200	$709,600[c]	$4,549,400	2.8	$1,141,900	$190,000	$3,046,700	13.1%	23.3%	$2.47[c]	$1.40	3.3%	$ 55¾–28¼	17.0
1986	4,835,900	589,500	3,993,900	2.5	1,070,000	221,900	2,646,500	12.2	22.3	2.07	1.06	2.9	44⅛–30⅛	18.0
1985	4,444,000	531,400	3,557,300	2.3	925,800	222,000	2,287,100	12.0	23.2	1.93	0.905	3.1	34¼–24½	15.2
1984	4,189,400	472,400	3,100,800	2.4	791,100	191,600	1,998,100	11.3	23.6	1.72	0.75	3.2	26¼–20½	13.6
Eli Lilly & Co.														
1987	$3,643,800[d]	$410,500	$4,859,200	1.8	$1,642,500	$344,100	$2,646,900	11.3%	15.5%	$2.83[d]	$2.00	2.4%	$107¾–57¾	29.2
1986	3,720,400	558,200	4,117,000	1.7	1,527,600	283,000	2,260,800	15.0	24.7	4.01	1.80	2.7	83½–50⅝	16.7
1985	3,270,600	517,600	3,859,400	1.7	1,374,000	207,100	2,293,400	15.8	22.6	3.69	1.60	3.6	55⅞–32¼	11.9
1984	3,109,200	490,200	3,556,500	1.6	1,280,400	205,300	2,133,800	15.8	23.0	3.36	1.49	4.9	33¾–26½	9.0
Merck & Co.														
1987	$5,061,300	$906,400	$5,533,200	1.3	$1,948,000	$253,700	$1,969,900	17.9%	46.0%	$2.23	$0.82	1.4%	$ 74¼–40⅝	25.8
1986	4,128,900	675,700	4,967,900	1.7	1,906,200	210,600	2,431,800	16.4	27.8	1.62	0.63	1.9	43⅛–22¾	20.3
1985	3,547,500	539,900	4,805,100	1.9	1,882,800	237,600	2,536,900	15.2	21.3	1.26	0.53	2.8	23–15	15.0
1984	3,559,665	492,967	4,489,697	1.9	1,912,778	274,425	2,443,260	13.8	20.2	1.12	0.50	3.4	16¼–13	13.1
Pfizer														
1987	$4,919,800	$690,200	$6,684,700	2.0	$1,505,900	$258,300	$3,644,500	14.0%	18.9%	$4.08	$1.80	3.1%	$ 77–40	14.3
1986	4,476,000	660,000	4,946,700	1.9	1,351,300	196,100	3,198,200	14.7	20.6	3.90	1.64	2.8	72⅞–46¼	15.3
1985	4,024,500	579,700	4,341,500	2.1	1,268,300	195,800	2,805,900	14.4	20.7	3.44	1.48	3.2	56¼–37⅝	13.6
1984	3,854,500	507,900	3,927,700	2.1	1,155,600	144,000	2,365,100	13.2	21.5	3.08	1.32	3.7	42⅜–29⅜	11.6
Schering-Plough Corp.														
1987	$2,699,300	$320,700[e]	$3,053,200	1.2	$1,131,100	$118,000	$1,317,36[illegible]	11.9%	24.3%	$2.77[e]	$1.025	2.4%	$ 55¼–31¼	15.6
1986	2,398,700	265,800	2,862,000	1.3	1,143,500	124,800	1,319,70[illegible]	11.1	20.1	2.17	0.90	2.5	44–28	16.6
1985	1,927,100	192,600	2,683,800	1.4	991,800	140,300	1,389,600	10.0	13.9	1.88	0.84	3.3	33¼–17⅝	13.5
1984	1,874,300	177,200	2,436,200	1.2	912,400	173,700	1,235,100	9.5	14.3	1.75	0.84	4.6	20–16½	10.4
SmithKline Beckman Corp.														
1987	$4,328,800	$570,100	$4,005,600	1.2	$1,480,200	$224,000	$1,144,000	13.2%	49.8%	$4.50	$1.62	2.9%	$ 72¾–39⅜	12.5
1986	3,745,400	521,100	3,891,400	1.3	1,410,800	237,000	965,400	13.9	54.0	3.39	1.50	3.4	52⅝–36¾	13.2
1985	3,256,600	514,400	3,534,500	1.8	1,285,300	248,000	2,070,100	15.8	24.8	3.28	1.425	4.3	39⅜–26⅛	10.1
1984	2,949,200	500,300[f]	3,077,600	2.0	1,093,000	241,500	1,952,100	17.0	25.6	3.10[f]	1.40	5.1	30⅛–25	8.9
Squibb Corp.														
1987	$2,156,503	$358,441	$2,782,375	1.5	$ 784,841	$166,539	$1,525,451	16.6%	23.5%	$3.42	$1.20	1.5%	$102⅞–55¼	23.1
1986	1,784,629	263,639[g]	2,408,831	1.8	645,630	95,077	1,358,096	14.8	19.4	2.45[g]	0.97	1.9	62–38⅛	20.4
1985	2,041,745	226,599	2,396,592	2.0	701,439	120,342	1,409,382	11.1	16.1	2.10	0.86	2.6	41¼–24⅞	15.7
1984	1,886,037	197,172	2,072,188	2.1	617,724	115,629	1,266,517	10.5	15.6	1.84	0.74	3.2	27¼–18¾	12.5
Upjohn Co.														
1987	$2,521,024	$305,039	$3,043,131	1.9	$1,114,391	$211,976	$1,673,512	12.1%	18.2%	$1.63	$0.63	1.6%	$ 53¾–23¼	23.6
1986	2,280,325	252,646	2,664,956	1.9	981,549	201,920	1,470,216	11.1	17.2	1.35	0.51	1.8	35½–20½	20.7
1985	2,008,486	203,193[h]	2,376,8[illegible]	1.8	852,054	152,637	1,295,085	10.1	15.7	1.10[h]	0.45	2.6	23⅝–11⅛	15.8
1984	2,179,060	173,272	2,248,363	1.5	809,534	136,738	1,134,154	8.0	15.3	0.94	0.43	4.4	12–7½	10.3
Warner-Lambert Co.														
1987	$3,484,700	$295,800	$2,396,500	1.1	$ 959,800	$176,900	$ 795,000	8.5%	37.2%	$4.15	$1.77	2.0%	$ 87½–48¼	16.4
1986	3,102,918	261,784[i]	2,479,054	1.4	819,291	137,996	870,453	8.4	30.1	3.54[i]	1.59	2.9	63¼–45	15.3
1985	3,200,069	237,704[j]	2,286,187	1.2	868,931	138,774	819,279	7.4	29.0	3.05[j]	1.50	3.2	49⅜–33¾	13.6
1984	3,166,657	223,887	2,377,098	1.5	863,179	142,461	910,125	7.1	24.6	2.81	1.48	4.6	36¼–28⅜	11.5

[a] Includes gain on sale of Brach confectionary business and Household Research subsidiary, before taxes, of $535 million. [b] From continuing operations; excludes net income from operations and net gain on sale of discontinued businesses of $76.3 million ($0.50 per share). [c] Includes gain on sale of orthodontic and animal health businesses, before taxes, of $80.3 million. [d] From continuing operations; includes restructuring charges, before taxes, of $271.9 million but excludes net income and net gain on sale of discontinued cosmetics business of $233.2 million ($1.58 per share). [e] Excludes nonrecurring net charge of $4.3 million ($0.04 per share). [f] Excludes net gain on sale of Industrial Business Group of $3.3 million ($0.02 per share). [g] From continuing operations; excludes net income from discontinued operations of $13.1 million ($0.12 per share), net gain on disposal of discontinued operations of $187.6 million ($1.75 per share), and extraordinary net charge for write-off of certain foreign assets of $68.0 million ($0.63 per share). [h] From continuing operations; excludes net loss from operations and sale of polymer chemical business of $238,000. [i] Excludes net nonrecurring credit from write-down and divestiture of assets and restructuring program of $47.7 million ($0.64 per share). [j] Excludes net nonrecurring charge for write-down and divestiture of assets and restructuring program of $553.3 million ($7.10 per share).

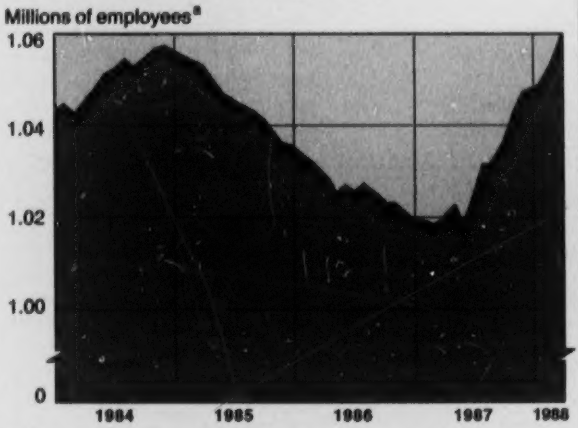
Chemical work force edges higher

Overall employment in the U.S. chemical industry reversed a two-year decline begun in 1984. The increase—less than 1%—was slight, however, and the total work force in 1987 was still 4% below what it was a decade earlier. The number of workers rose the most in the drug and soap, cleaners, and toilet goods sectors, but it continued to fall or remained almost steady in most other sectors. The largest decline occurred in industrial organic chemicals, employment in which fell about 2% to a level 8% below what it was 10 years ago.

Major chemical firms again reduced their ranks of employees, but only 5% rather than the deep cut of 24% seen in 1986. Those companies that hired more workers did so in relatively small increments, however.

Total employment of scientists and engineers in the chemical industry, however, witnessed an unusual reversal of the nearly steady rise that has been going on for more than a decade. As a group, scientists until last year had been much more immune to substantial cuts than other chemical workers.

Number of workers in chemical industry rebounds to level of late 1984



a Seasonally adjusted employment in U.S. chemicals and allied products industry; March and April 1988 figures are preliminary. Source: Department of Labor

INDUSTRIAL EMPLOYMENT: Slightly lower for industrial chemicals last year

	All employees[a] (thousands)				Production workers[a] (thousands)				Workweek[a,b] (hours)			
	1987	1986	1985	1977	1987	1986	1985	1977	1987	1986	1985	1977
All manufacturing	19,112	18,994	19,260	19,682	13,021	12,895	13,092	14,135	41.0	40.7	40.5	40.3
Chemicals and allied products	1,026	1,023	1,044	1,073	575	568	578	616	42.3	41.9	41.9	41.7
Industrial inorganic chemicals	134	136	142	162	68	70	72	95	42.6	42.0	41.7	41.9
Plastics materials and synthetics	166	167	172	215	109	113	114	142	43.1	42.1	42.3	43.4
Drugs	212	207	206	181	97	96	95	90	41.5	41.6	41.1	41.0
Soap, cleaners, and toilet goods	153	147	148	130	97	93	94	78	41.1	41.0	41.0	40.7
Paints and allied products	63	63	64	66	31	31	31	35	41.7	41.6	41.4	41.2
Industrial organic chemicals	152	155	160	166	86	82	82	84	44.1	43.4	43.3	42.7
Agricultural chemicals	54	55	59	68	34	34	37	42	42.8	42.2	42.7	43.0
Miscellaneous chemical products	94	93	94	87	53	52	54	50	41.4	41.3	41.9	41.8
Petroleum and coal products	165	169	179	202	108	106	109	131	43.9	43.8	43.0	42.7
Rubber and miscellaneous plastics products	818	790	786	714	636	614	607	558	41.6	41.3	41.1	41.0

a Domestic employment. b Workweek of production or nonsupervisory workers. Source: Department of Labor

EMPLOYMENT OF SCIENTISTS, ENGINEERS: Increases by chemical producers were modest

Thousands[a]	1987[b]	1986[b]	1985	1984	1983	1982	1981	1980	1979	1978	1977
Total, all industry	610.0	580.3	560.2	544.5	522.1	509.8	487.8	450.6	423.9	404.4	382.8
Chemicals and allied products	66.2	70.0	67.0	67.1	66.0	61.6	54.7	51.4	50.0	48.3	46.4
Industrial chemicals	27.1	27.1	25.0	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6
Drugs and medicines	29.0[c]	31.6[c]	30.7[c]	30.1[c]	28.2	25.6	23.3	21.6	20.8	19.5	17.8
Other chemicals	10.1	11.3	11.3	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0
Petroleum refining	8.5	10.3	13.4	13.2	14.7	15.8	13.0	10.8	10.1	9.9	8.9
Rubber products	12.5	13.0	13.0	na	na	8.1	10.3	na	8.1	7.9	9.1

a Full-time equivalent number of R&D scientists and engineers in industry, as of January of each year. b Preliminary. c Partly estimated. na = not available separately, but included in total. Source: National Science Foundation

CHEMICAL EMPLOYMENT: Declined further in 1987, leading sales per employee to improve

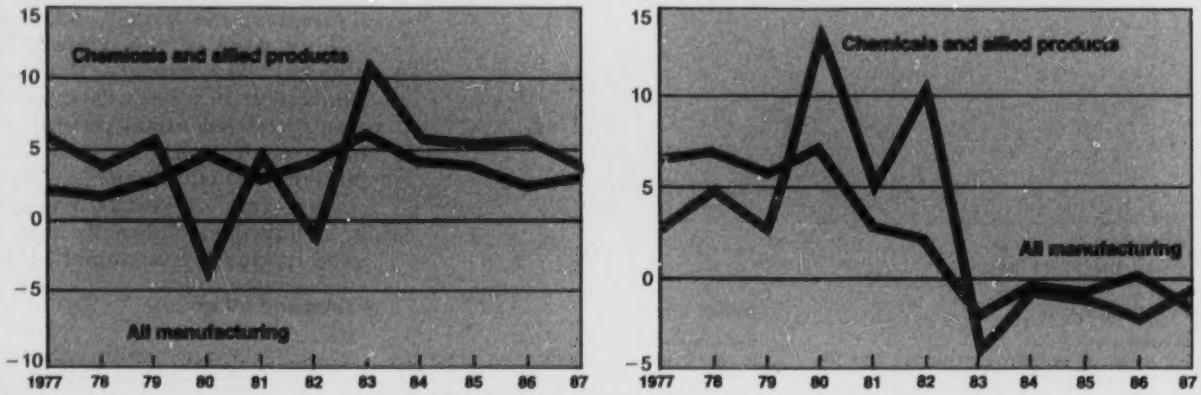
Thousands	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Air Products	12.1	16.6	18.7	17.7	16.7	18.9	16.2	15.8	14.6	14.3	13.7
American Cyanamid	34.3	34.5	36.4	38.2	38.7	40.2	41.8	42.6	44.2	44.0	43.8
Betz Laboratories	2.0	2.6	2.5	2.5	2.3	2.2	2.2	2.1	2.0	1.8	1.6
Cabot Corp.	5.1	6.6	7.7	7.5	7.2	7.5	7.7	7.6	8.1	7.9	5.6
Chemed	4.8	4.8	4.3	4.3	4.1	3.5	3.6	3.6	3.3	3.1	3.0
Crompton & Knowles	1.3	1.3	2.3	2.3	2.4	2.3	2.5	2.8	3.0	3.2	3.1
Dow Chemical	53.1	51.3	53.2	49.8	54.5	56.6	63.8	56.8	55.9	53.5	53.2
Ethyl	10.0	10.5	10.5	11.0	13.0	14.0	14.5	15.0	16.0	16.5	16.0
H. B. Fuller	4.6	4.5	4.4	4.3	4.1	4.0	3.3	3.4	3.4	3.3	3.0
W. R. Grace	39.4	41.4	116.9	102.6	95.5	82.2	89.0	92.0	82.8	69.1	69.1
Hercules	23.2	25.1	25.4	26.3	24.2	24.5	25.9	26.1	27.4	27.1	26.3
International Flavors	4.1	3.8	3.7	3.7	3.7	3.6	3.6	3.6	3.6	3.5	3.3
International Minerals	12.9	13.9	8.7	9.0	8.4	8.4	10.6	10.6	10.3	9.9	9.9
Lubrizol	4.8	4.8	5.2	4.2	4.2	4.3	4.2	4.2	3.9	3.8	3.6
Monsanto	49.7	51.7	56.1	50.8	48.8	52.2	57.4	61.8	63.9	62.9	61.5
Nalco Chemical	5.1	4.9	5.1	4.8	4.6	4.6	4.7	4.3	4.1	4.1	4.2
Olin	14.1	13.2	14.9	17.8	18.2	17.5	20.3	21.0	21.7	22.7	22.4
Pennwalt	9.0	9.6	9.9	9.8	9.8	9.5	10.7	12.8	13.3	14.0	13.9
PPG Industries	36.8	36.5	37.5	37.7	37.0	37.0	36.6	37.3	38.2	37.4	36.6
Rohm & Haas	12.0	12.1	11.8	11.9	11.4	11.5	13.5	13.2	13.3	13.1	13.0
Stepan	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.8	0.9	0.8	0.8
Union Carbide	43.1	50.3	91.5	98.4	99.5	103.2	110.3	116.1	115.8	113.4	113.7
TOTAL EMPLOYEES	**382.6**	**400.9**	**527.6**	**515.5**	**509.1**	**508.6**	**543.3**	**553.4**	**549.7**	**529.5**	**521.4**
ANNUAL CHANGE	**−4.6%**	**−24.0%**	**2.4%**	**1.2%**	**0.1%**	**−6.4%**	**−1.8%**	**0.7%**	**3.8%**	**1.6%**	**2.4%**
SALES PER EMPLOYEE ($ thousands, current)	**$159.9**	**$135.3**	**$114.4**	**$115.5**	**$110.0**	**$107.7**	**$109.3**	**$101.8**	**$ 92.6**	**$ 79.7**	**$ 73.0**
SALES PER EMPLOYEE ($ thousands, constant 1982[a])	**$150.3**	**$132.0**	**$110.3**	**$112.3**	**$109.8**	**$107.7**	**$111.0**	**$114.3**	**$121.6**	**$117.1**	**$110.7**

Note: Data are not restated for acquisitions, divestitures, or similar developments. a Based on producer price index for chemicals and allied products.

WAGES: Steady rise of recent years continued for chemical workers

	Hourly earnings[a]				Weekly earnings[a]			
	1987	1986	1985	1977	1987	1986	1985	1977
All manufacturing	$ 9.91	$ 9.73	$ 9.54	$5.68	$406.31	$396.01	$386.37	$228.90
Chemicals and allied products	12.37	11.98	11.56	6.43	523.25	501.96	484.36	268.13
Industrial inorganic chemicals	13.62	13.12	12.80	6.99	580.21	551.04	533.76	292.88
Plastics materials and synthetics	12.52	12.12	11.71	6.29	539.61	510.25	495.33	262.92
Drugs	11.64	11.16	10.75	5.99	483.06	464.26	441.83	245.59
Soap, cleaners, and toilet goods	10.87	10.73	10.28	6.13	446.76	439.93	421.07	249.49
Paints and allied products	10.82	10.43	10.08	5.91	451.19	433.89	417.31	243.49
Industrial organic chemicals	14.88	14.39	13.98	7.42	656.21	624.53	605.33	316.83
Agricultural chemicals	11.98	11.46	11.03	6.03	512.74	483.61	470.98	259.29
Miscellaneous chemical products	11.38	11.08	10.61	6.02	471.13	457.60	444.56	251.64
Petroleum and coal products	14.57	14.18	14.06	7.83	639.62	621.08	604.58	334.34
Rubber and miscellaneous plastics products	8.88	8.73	8.54	5.17	369.41	360.55	350.99	211.97

a For production and nonsupervisory workers in domestic employment. **Source:** Department of Labor



Productivity growth slowed for chemicals . . . . . . so that unit labor costs fell only slightly

Note: Productivity is output per workhour, calculated by dividing indexes for production by indexes for workhours of production employees. Unit labor costs are labor costs per unit of output, calculated by dividing indexes for wages by indexes for output per workhour. **Sources:** Federal Reserve Board, Department of Labor, C&EN estimates

The U.S. chemical industry continued to become more productive for the fifth straight year in 1987. But the growth of productivity slowed considerably from that during the four previous years.

Productivity in the U.S. chemical industry rose last year as production increased 5.3%, outstripping the 1.4% rise for workhours. This is in contrast to the previous two years, when workhours in the industry were falling as output was rising.

Using data from government agencies, C&EN figures that chemical industry productivity (output per workhour) rose 3.9% in 1987. This compares with a 3.6% rise for all manufacturing industries, narrowing the gap between the two. In 1986, productivity growth for chemicals and allied products was 5.5%, compared with only 2.5% for all manufacturing. For 1987, production for all manufacturing increased 4.2% and workhours rose 0.6%.

The pattern for unit labor costs (labor costs per unit of output) was essentially the same as that for productivity. Hourly production wages rose 3.4% for all chemicals but increased a much lower 1.9% for all manufacturing. As a result, the decrease in unit labor costs for chemicals was less than that for all manufacturing for the first time in the past five years.

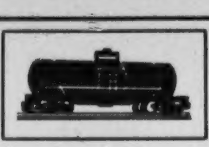
Unit labor costs for chemicals fell only 0.5% in 1987 from the year-earlier level, whereas the same index for all manufacturing fell 1.6%. In 1986, chemical unit labor costs declined 2.0% while unit labor costs for all manufacturing rose a slight 0.1%.

PRODUCTIVITY: Gains persisted as output climbed while workhours were little changed

Indexes, 1977 = 100	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
CHEMICALS AND ALLIED PRODUCTS											
Production	140.0	133.0	127.1	121.6	113.9	103.8	112.6	106.4	113.3	106.3	100.0
Workhours	94.8	93.5	94.3	95.0	93.9	95.2	101.7	101.0	103.1	102.2	100.0
Productivity	147.7	142.2	134.8	128.0	121.3	109.0	110.7	105.4	109.9	104.0	100.0
Hourly production wages	192.4	186.1	180.1	172.7	164.8	155.0	141.8	129.2	118.2	109.2	100.0
Unit labor costs	130.3	130.9	133.7	135.0	135.9	142.2	128.2	122.6	107.6	105.0	100.0
ALL MANUFACTURING											
Production	134.6	129.2	126.4	123.4	113.9	102.2	110.5	108.2	110.7	106.1	100.0
Workhours	93.6	93.0	93.3	94.8	88.2	87.0	97.9	98.9	106.4	104.5	100.0
Productivity	143.8	138.8	135.5	130.1	124.8	117.5	112.9	109.4	104.2	101.5	100.0
Hourly production wages	174.4	171.1	166.9	161.5	155.4	149.6	140.7	128.1	118.0	108.6	100.0
Unit labor costs	121.6	123.3	123.2	124.1	124.4	127.3	124.7	121.5	113.2	107.0	100.0

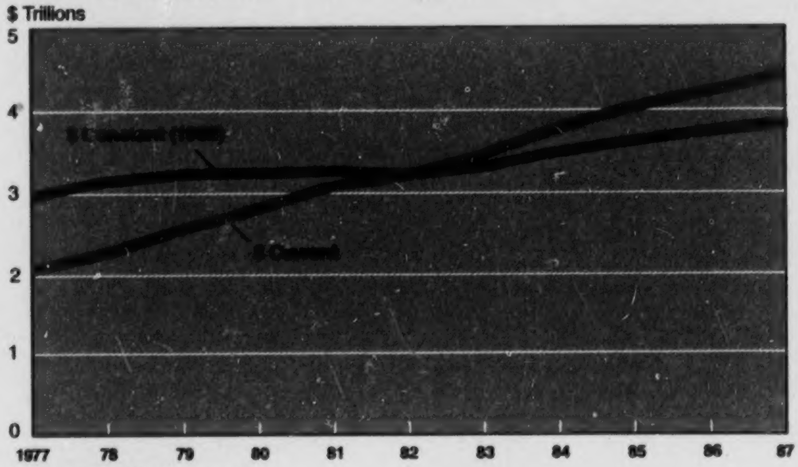
Sources: Federal Reserve Board, Department of Labor, C&EN estimates

4 Markets for the U.S. Chemical Industry



Gross national product

$ Trillions



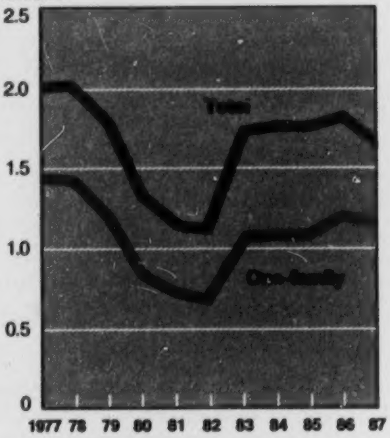
Source: Department of Commerce

No industry can long outperform its best customers. These two pages present a series of graphical snapshots depicting recent trends among some of the most significant consumers of chemicals.

Because its products are so diverse and their uses so broad, the U.S. chemical industry finds markets throughout the varied and interlocking parts of the overall U.S. economy. The industry, therefore, has reaped rich rewards from the steady and restrained growth that the economy has undergone since pulling itself out of the 1981–82 recession. The five-year recovery has been largely fueled, moreover, by steadily growing consumer spend-

Housing starts

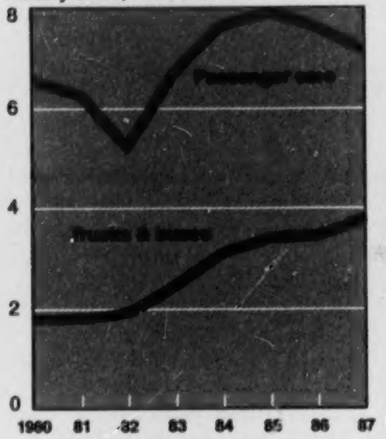
Millions



Source: Bureau of the Census

Motor vehicles

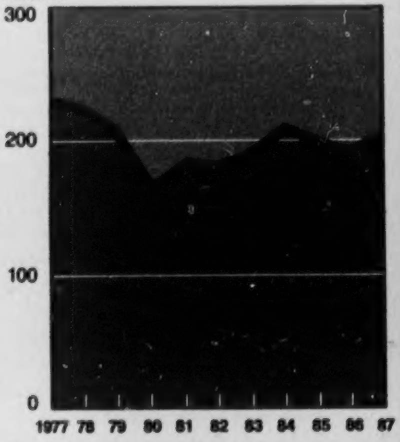
Factory sales, millions of units



Source: Motor Vehicle Manufacturers Association

Tires and tubes

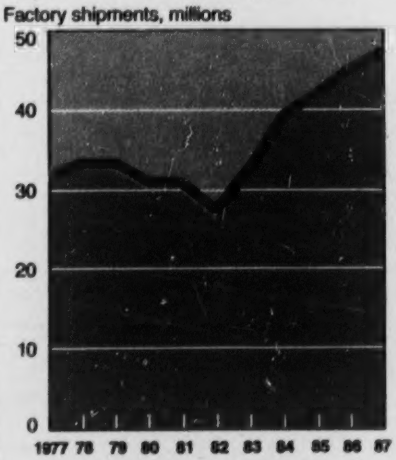
Millions



Source: Rubber Manufacturers Association

Major home electrical appliances

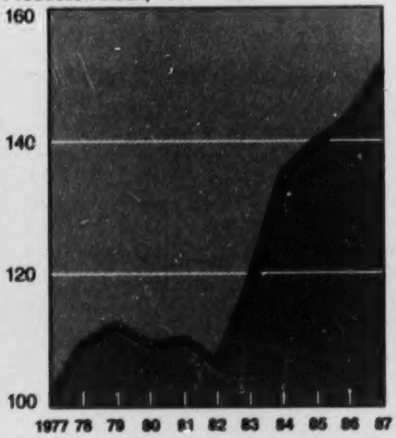
Factory shipments, millions



Source: Association of Home Appliance Manufacturers

Furniture and fixtures

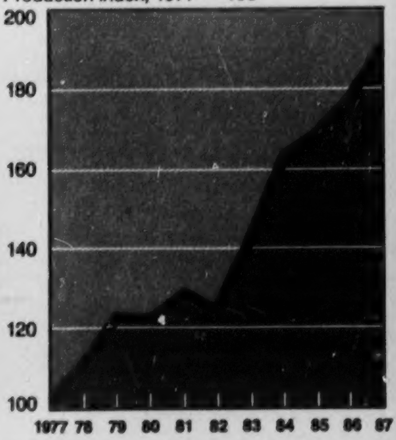
Production index, 1977 = 100



Source: Federal Reserve Board

Miscellaneous plastics products

Production index, 1977 = 100

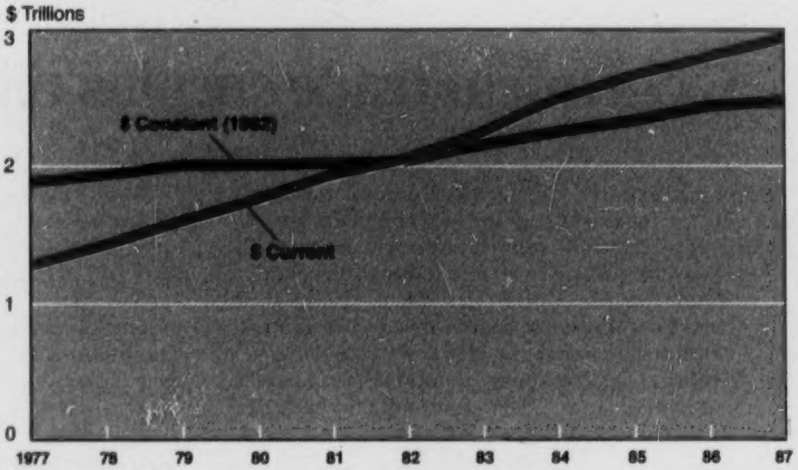


Source: Federal Reserve Board

ing—and the bulk of the industry's products eventually wind up in products bought by consumers.

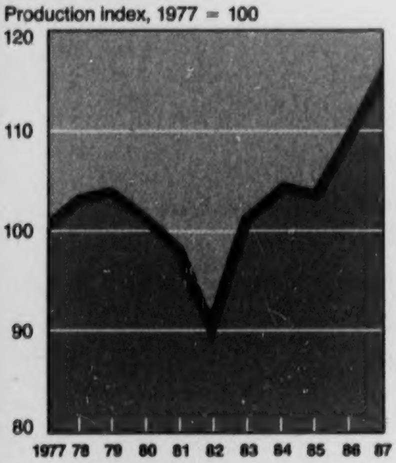
Some of the industry's most important outlets, nonetheless, have recently been under strain—notably new housing, pinched by rising land and construction costs and higher mortgage rates, and new cars, which continue to be buffeted by rising sales of imported vehicles. On the other hand, demand has been strong for apparel and home furnishings. Business also has been good for paper producers and furniture manufacturers—and especially so for makers of miscellaneous plastics products, which consume about half of all U.S. output of plastics.

Personal consumption expenditures



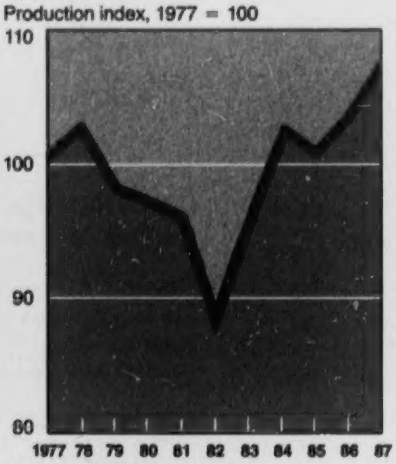
Source: Department of Commerce

Textile mill products



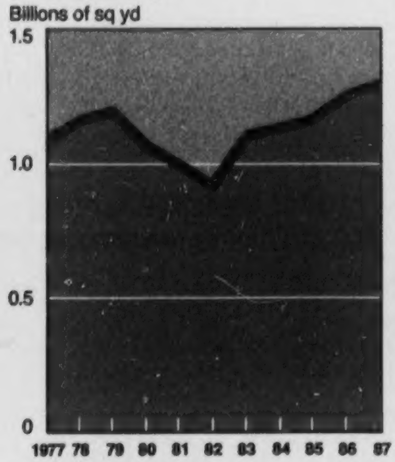
Source: Federal Reserve Board

Apparel



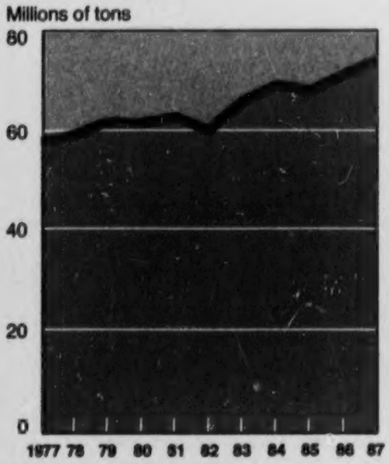
Source: Federal Reserve Board

Floor coverings



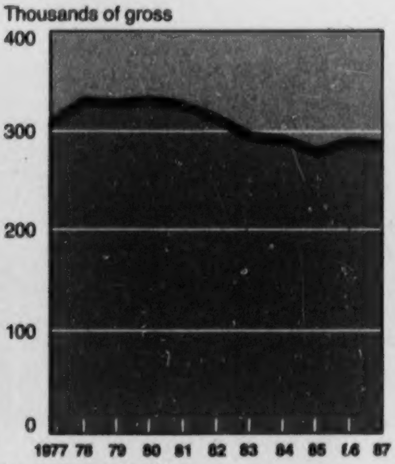
Source: Bureau of the Census

Paper and paperboard



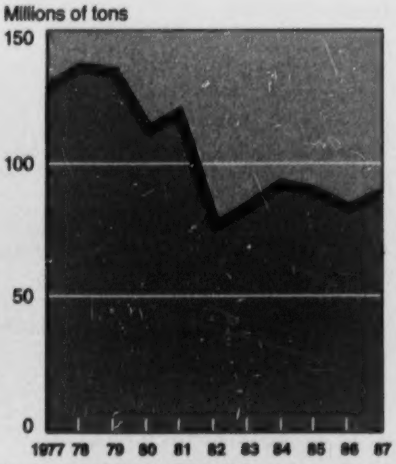
Source: American Paper Institute

Glass containers



Source: Bureau of the Census

Steel



Source: American Iron & Steel Institute

U.S. chemical trade surplus rebounds

U.S. chemical exports, riding the wings of a sharply weaker dollar, increased a hefty 16% last year, virtually twice the increase of chemical imports. As a result, the U.S. chemical industry was able to boost its heralded trade surplus from $7.8 billion in 1986 to $10.2 billion and now appears poised to match or surpass the record $12.1 billion surplus that it chalked up in 1980.

The achievement has been a long time coming. After its record year in 1980, the industry suffered through a five-year spell that saw its trade surplus plunge to a lowly $7.2 billion in 1985. During that time, chemical exports grew a mere 5%. Imports, meanwhile, had surged 69%.

Since 1985, however, the industry's trade fortunes have been improving. Last year, chemical exports advanced to a record $26.4 billion. Imports managed a healthy, but less impressive 8% gain to $16.2 billion—also a record.

Despite this impressive performance, the U.S. chemical industry's share of world chemical exports is declining. It dropped from 14.0% in 1986 to 13.2% last year. In 1984, it had been a lofty 16.8%.

How can this be, when the industry's trade performance has been so strong during the past two years? The answer lies in the dramatic changes in currency exchange rates.

As currencies of major foreign countries have become stronger against the U.S. dollar, the value of their respective chemical exports has become inflated if they are expressed in dollars. For instance, chemical exports of the European Community rose 22% last year, measured in dollars. However, if European Currency Units are the yardstick, the community's chemical exports increased only 4%. That is why, on a dollar basis, total world exports of chemicals were up an unlikely 21% last year to $216 billion.

U.S. TOTAL TRADE BALANCE: Deficit practically unchanged last year

$ Billions	1987	1986	1985	1977
Total exports	$252.9	$217.3	$213.1	$121.2
Total imports	405.9	370.0	345.3	147.7
Trade balance	−153.0	−152.7	−132.2	−26.5

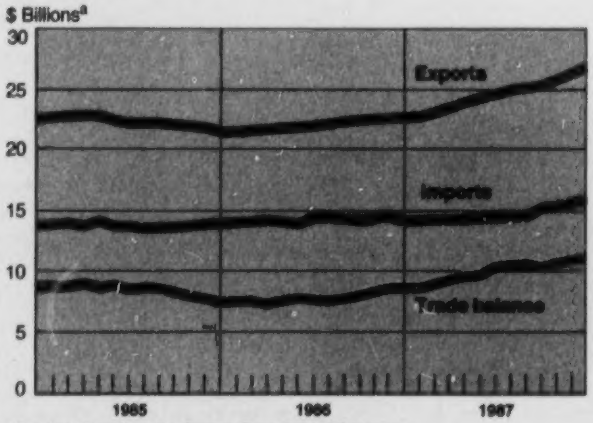
Source: Department of Commerce

U.S. CHEMICAL TRADE BALANCE: Surplus widened appreciably

$ Millions	1987	1986	1985	1977
Chemical exports	$26,381	$22,766	$21,759	$10,827
Chemical imports	16,213	15,001	14,533	5,432
Chemical trade balance	10,168	7,765	7,226	5,395

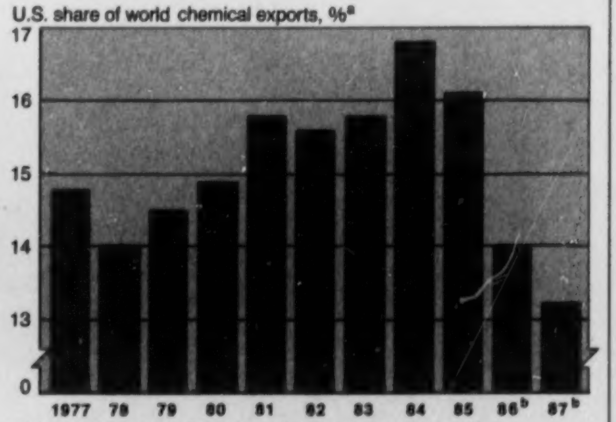
Source: Department of Commerce

Export surge bolstered U.S. chemical trade surplus . . .



a Running 12-month totals. **Source:** Department of Commerce

. . . but slumping exchange rates depressed U.S. market share



a U.S. chemical exports as a percentage of total world chemical exports less U.S. chemical imports. b C&EN estimate. **Source:** Department of Commerce

U.S. TRADE: Higher in most world markets

$ Millions	1987	1986	1985	1977
U.S. CHEMICAL EXPORTS				
Canada	$ 3,324	$ 2,668	$ 2,698	$ 1,539
Western Europe	8,020	7,032	6,742	3,737
Eastern Europe	343	385	368	78
Communist Asia	739	441	513	20
Japan	3,430	3,081	2,908	977
Rest of Asia	4,115	3,377	3,024	955
Middle East	422	345	400	269
Latin America	4,406	4,025	3,681	2,350
Australasia	844	689	704	384
Africa	501	447	456	309
Other	237	276	265	209
TOTAL	**$26,381**	**$22,766**	**$21,759**	**$10,827**
U.S. CHEMICAL IMPORTS				
Canada	$ 3,048	$ 2,752	$ 2,913	$1,451
Western Europe	8,204	7,357	7,118	2,465
Eastern Europe	162	327	380	33
Communist Asia	195	179	163	22
Japan	2,172	1,792	1,412	465
Rest of Asia	697	623	457	89
Middle East	243	238	218	35
Latin America	957	942	1,216	212
Australasia	227	221	231	402
Africa	81	326	203	46
Other	227	244	222	212
TOTAL	**$16,213**	**$15,001**	**$14,533**	**$5,432**

Source: Department of Commerce

WORLD TRADE: Value in dollars up sharply

$ Millions	1987	1986	1985	1977
CHEMICAL EXPORTS				
World	$215,700[a]	$178,000[a]	$149,926	$78,225
U.S.	26,381	22,766	21,759	10,827
Canada	4,765	4,064	4,040	1,696
EC, 12 countries	119,898	97,961	80,513	44,278
Belgium-Luxembourg	9,691	8,597	6,882	4,620
France	19,862	16,763	13,715	7,162
Italy	9,087	7,060	6,608	3,156
Netherlands	16,824	13,786	11,324	6,321
U.K.	17,311	14,205	12,174	6,753
West Germany	38,105	31,202	24,253	14,216
Switzerland	9,660	8,124	5,879	3,580
Japan	11,662	9,484	7,697	4,300
CHEMICAL IMPORTS				
U.S.	$16,213	$15,001	$14,533	$ 5,432
Canada	5,340	4,758	4,454	2,347
EC, 12 countries	96,270	78,167	61,888	32,988
Belgium-Luxembourg	8,688	7,119	5,735	3,359
France	16,828	13,708	10,826	5,948
Italy	13,610	11,001	8,476	3,776
Netherlands	9,690	7,889	6,573	3,635
U.K.	13,500	10,772	8,896	4,303
West Germany	21,442	17,686	14,118	7,503
Switzerland	5,659	4,796	3,665	2,012
Japan	11,845	9,733	8,072	3,003

[a] C&EN estimates. **Sources:** United Nations, Organization for Economic Cooperation & Development, European Community, individual country data

U.S. TRADE, BY PRODUCTS: Strong gains for organic and inorganic chemicals and plastics

	Chemical exports				Chemical imports			
$ Millions	1987	1986	1985	1977	1987	1986	1985	1977
Organic chemicals	$ 7,550	$ 6,293	$ 6,012	$ 3,286	$ 5,408	$ 4,704	$ 4,576	$1437
Inorganic chemicals	2,112	1,771	1,967	1,047	2,030	1,894	1,984	1175
Radioactive materials	1,017	1,302	1,311	551	1,012	1,382	1,417	484
Dyeing, tanning, and coloring materials	217	174	139	126	621	487	352	142
Pigments, paints, and varnishes	411	333	322	227	427	348	266	44
Medicinals and pharmaceuticals	3,182	3,090	2,708	1,080	1,456	1,240	1,084	318
Flavors, perfumes, cosmetics, and toiletries	579	488	478	274	796	679	577	175
Cleaning and polishing materials	357	302	292	195	205	214	172	49
Fertilizer, manufactured	2,259	1,935	2,160	701	795	865	967	829
Explosives and pyrotechnics	91	81	100	78	110	111	103	36
Plastics and resins	5,492	4,301	3,777	1,732	1,987	1,837	1,631	389
Pesticides and disinfectants	732	664	614	a	398	580	399	a
Miscellaneous	2,382	2,032	1,878	1,530	968	660	1,005	354
TOTAL	**$26,381**	**$22,766**	**$21,759**	**$10,827**	**$16,213**	**$15,001**	**$14,533**	**$5432**

a Included in miscellaneous chemical products. **Source:** Department of Commerce

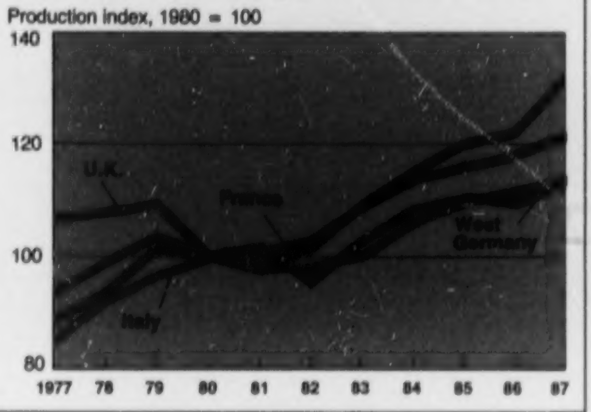
6 Foreign Chemical Industries—Western Europe

In 1987, West Germany's three largest chemical companies—BASF, Bayer, and Hoechst—were also the sales leaders in the West European chemical industry, although BASF nosed out Bayer for the top spot. They were followed by ICI of the U.K. and Montedison of Italy.

The weak U.S. dollar continued to affect financial results of the chemical industry. Corporate executives note that the translation of revenues from exports and foreign subsidiaries back into stronger home currencies depressed sales and, eventually, earnings. The dollar has fallen nearly 40% since 1985 against the currencies of some major European countries.

The fibers field in 1986 saw the dramatic increase in output from Turkey, which is pressing hard to join the European Community. Last year, fiber output in Turkey surpassed that in the U.K.

Chemical output has grown fastest in U.K.



CHEMICAL INDUSTRY TRENDS: Production and capital outlays higher, prices mixed

$ Billions (U.S.)	1987	1986	1985	1984	1983
WEST GERMANY					
Sales	$ 78.2	$ 64.5	$ 50.5	$ 49.5	$ 49.7
Exports	40.3	33.2	26.1	25.1	24.0
Imports	22.7	18.6	15.0	14.0	13.6
Capital spending	5.0	4.9	2.4	2.2	2.7
Production index[a]	112.7	110.1	111.1	108.8	103.4
Price index[a]	110.9	114.6	121.6	118.1	113.9
Employees (thousands)	572	567	557	550	549
FRANCE[b]					
Sales	$ 47.0	$ 39.5	$ 31.8	$ 30.9	$ 30.1
Exports	19.0	15.7	12.8	12.2	11.5
Imports	15.4	12.5	10.0	9.2	8.9
Capital spending	2.5	2.0	1.3	1.1	1.0
Production index[a]	121.1	117.5	116.3	114.3	108.7
Price index[a]	144.3	146.0	160.0	153.1	139.9
Employees (thousands)	264	269	272	279	282
ITALY					
Sales	$ 37.4	$ 30.7	$ 24.5	$ 23.6	$ 22.9
Exports	9.3	7.7	6.6	6.2	5.7
Imports	14.7	12.0	9.3	6.6	7.9
Capital spending	1.7	1.3	0.9	0.9	1.1
Production index[a]	114.3	111.6	110.3	106.2	100.0
Price index[a]	160.3	155.4	159.7	148.2	134.9
Employees (thousands)	225	230	233	241	251
U.K.[b]					
Sales	$ 37.3	$ 30.6	$ 26.3	$ 25.2	$ 25.6
Exports	17.1	14.1	12.1	11.0	10.5
Imports	13.6	10.7	9.0	8.8	8.1
Capital spending	2.3	1.9	1.6	1.4	1.4
Production index[a]	131.5	122.4	120.4	114.9	108.7
Price index[a]	136.5	133.4	131.6	125.1	119.1
Employees (thousands)	337	335	336	329	330
SPAIN[b,c]					
Sales	$ 25.5	$ 20.7	$ 16.1	$ 15.2	$ 14.2
Exports	4.2	3.1	2.9	2.7	2.2
Imports	6.3	4.7	3.1	3.0	2.8
Capital spending	0.4	0.4	0.3	0.2	0.3
Production index[a]	128.2	119.6	113.9	111.0	104.5
Price index[a]	180.4	177.7	175.9	163.6	147.4
Employees (thousands)	239	239	240	241	242

$ Billions (U.S.)	1987	1986	1985	1984	1983
BELGIUM[b,c,d]					
Sales	$ 19.7	$ 17.2	$ 14.1	$ 13.6	$ 13.2
Exports[d]	14.6	12.2	9.6	9.1	8.8
Imports[d]	10.6	9.2	6.9	6.6	6.3
Capital spending	0.9	0.7	0.4	0.4	0.4
Production index[a]	120.5	119.8	117.1	113.3	107.3
Price index[a]	136.4	141.6	145.0	139.9	133.7
Employees (thousands)	91	91	90	89	88
NETHERLANDS					
Sales	$ 19.5	$ 16.0	$ 13.9	$ 13.6	$ 13.1
Exports	19.0	15.7	12.9	12.5	12.0
Imports	11.5	9.5	8.0	7.2	6.8
Capital spending	1.6	1.1	0.8	0.8	0.7
Production index[a]	140.0	131.0	133.0	122.0	111.0
Price index[a]	105.0	105.0	123.0	116.0	115.0
Employees (thousands)	91	91	89	89	88
SWITZERLAND[b]					
Sales	$ 11.5	$ 9.3	$ 6.7	$ 6.5	$ 6.7
Exports	9.6	7.9	5.7	5.4	5.5
Imports	5.6	4.7	3.6	3.4	3.3
Production index[a]	129.5	125.5	122.9	115.7	109.6
Price index[a]	103.3	110.7	113.8	109.1	106.4
Employees (thousands)	69	68	66	65	68
SWEDEN					
Sales	$ 6.2	$ 5.0	$ 4.1	$ 4.1	$ 3.9
Exports	3.0	2.5	1.9	1.8	1.8
Imports	3.9	3.2	2.7	2.5	2.7
Capital spending	0.5	0.4	0.3	0.3	0.3
Production index[a]	121.2	111.5	114.0	114.6	113.2
Price index[a]	160.5	158.0	155.5	147.0	135.5
Employees (thousands)	45	43	43	44	43
NORWAY					
Sales	$ 2.9	$ 2.4	$ 2.0	$ 2.1	$ 2.1
Exports	1.6	1.3	1.2	1.2	1.1
Imports	1.6	1.4	1.1	1.0	0.9
Capital spending	0.2	0.2	0.1	0.1	0.1
Production index[a]	153.1	146.7	126.0	121.0	110.0
Price index[a]	134.0	127.0	127.0	128.1	123.6
Employees (thousands)	15	15	15	16	17

a 1980 = 100. b Excludes fibers. c Includes rubber and plastics processing. d Includes Luxembourg for exports and imports. Sources: National agencies and European Council of Chemical Manufacturers' Federations (CEFIC)

MAN-MADE FIBERS: Growth in output spotty for cellulosics, nil for noncellulosics

Millions of lb	1987		1986		1985		1984		1983		Change, 1986–87	
	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics[a]	Cellulosics	Non-cellulosics[b]	Cellulosics	Non-cellulosics	Cellu-losics
West Germany	1806	355	1738	354	1764	372	1674	359	1654	334	4%	0%
Italy	1441	64	1430	66	1409	67	1329	68	1166[a]	65	1	−3
Spain	591	78	608	80	633	80	599	73	539	70	−3	−2
Turkey	572	18	504	18	409	18	356	11	330	9	13	0
U.K.	501[c]	208[d]	525[c]	207[d]	557[c]	247[d]	561[c]	372[d]	541[c]	330[d]	−5	0
Benelux countries	399	109	379	108	365	95	318	94	189	90	5	1
France	382	50	392	45	427	44	456	61	437	83	−2	−11
Switzerland	210	0	216	0	226	0	218	0	204	0	−3	0
Ireland	172	0	162	0	140	0	136	0	118	0	6	0
Portugal	139	2	136	2	134	1	119	1	95	1	2	0
Austria	60	264	61	272	63	265	59	267	53	251	−2	−3
Finland	3	118	3	121	3	134	3	143	0	128	0	−2

a Includes polypropylene. b Excludes polypropylene. c Includes cellulose acetate filament. d Excludes cellulose acetate filament. **Source:** Comité International de la Rayonne et des Fibres Synthétiques

---

PRODUCTION: Higher for most chemicals, but the increases were generally modest

Millions of lb	1987	1986	1985	1984	Change 1986–87
FRANCE					
Sulfuric acid	8618	8826	9433	9898	−2%
Hydrochloric acid	1427	1381	1446	1686	3
Chlorine	2971	3151	3060	3103	−6
Sodium hydroxide	3123	3304	3196	3274	−5
Ammonia	4466	4455	4422	5170	0
Benzene	1439	1332	1399	1343	8
Toluene	72	83	89	87	−13
Xylenes	284	250	277	188	14
Ethylene	5319	4980	4740	4561	7
Propylene	3073	2283	2730	2652	35
Butadiene	677	641	634	667	6
Formaldehyde	180	176	203	210	2
Polyethylene	2523	2471	2266	2045	2
Polypropylene	1159	1034	933	871	12
Polystyrene	1166	1089	1074	1060	7
Polyvinyl chloride	2039	1960	1804	1737	4
Synthetic rubber	1184	1161	1199	1218	2
Phosphate fertilizer[a,b]	1209	1238	1340	1495	−2
ITALY					
Sulfuric acid	9598[a]	9170	9588	9370	5%
Nitric acid	2598[a]	2401	2599	2420	8
Phosphoric acid	848[a]	830	886	996	2
Chlorine	2288[a]	2106	2031	2095	9
Sodium hydroxide	2652[a]	2294	2268	2359	16
Sodium perborate	247[a]	214	218	229	15
Ammonia	3770[a]	4157	3250	3233	−9
Benzene	1313[a]	1106	1075	1179	19
Toluene	393[a]	512	766	688	−23
Xylenes	1080[a]	885	952	871	22
Formaldehyde	240[a]	297	301	325	−19
Acetic acid	140[a]	116	129	140	21
Carbon black	417[a]	418	403	380	0
Polyethylene	1674[a]	1504	1408	1602	11
Polystyrene	665[a]	785	707	695	−15
Polyvinyl chloride	1346[a]	1408	1358	1493	−4
Nitrogen fertilizers[c]	6890[a]	7052	7217	7134	−2

Millions of lb	1987	1986	1985	1984	Change 1986–87
U.K.					
Sulfuric acid	4796	5125	5621	5829	−6%
Hydrochloric acid[d]	384	346	337	345	11
Phosphoric acid	na	648	826	896	—
Chlorine	2256	2143	2269	2156	5
Benzene	2005	1876	1863	1660	7
Ethylene	3955	3828	3182	2913	3
Propylene	1929	1901	2141	2147	1
Butadiene	509	424	655	570	20
Formaldehyde	250	227	272	228	10
Acetone	259	271	323	355	−4
Polyethylene	882	940	1144	893	−6
Polypropylene	613	652	592	568	−6
Polyvinyl chloride	387	400	391	379	−3
Synthetic rubber	565	636	593	636	−11
WEST GERMANY					
Sulfuric acid	7260	7344	7571	8002	−1%
Hydrochloric acid	2179	2048	2079	2104	6
Nitric acid	5818	6210	6361	6284	−6
Chlorine	7595	7538	7686	7536	1
Sodium hydroxide	7523	7485	7581	7408	1
Sodium carbonate	3195	3173	3096	3000	1
Sodium sulfate	361	359	306	281	1
Carbon black	796	844	852	841	−6
Ammonia	5098	4146	5036	5183	23
Benzene	3316[e]	3373[e]	2723[f]	2734[f]	−2
Toluene	884	1052	860	816	−16
Xylenes	1102	1190	1089	1003	−7
Aniline	309	408	369	373	−24
Ethylene	6118	5868	6661	7093	4
Propylene	3467	3093	3665	3969	12
Butadiene	1543	1505	1851	1661	3
Ethylene oxide	1223	1093	1073	1044	12
Ethylene glycol	na	500	504	509	—
Propylene oxide	1181	1174	1179	1083	1
Propylene glycol	379	395	371	372	−6
***n*-Butanol**	689	689	604	589	0
Acetaldehyde	727	686	726	737	6
Acetic acid	704	653	655	668	8
Ethanol	240	217	170	120	11
Formaldehyde	1341	1265	1253	1283	6
Methanol	na	1016	1302	1504	—
Phthalic anhydride	522	433	378	453	21
Polyethylene	2980	2785	2725	2882	7
Polyvinyl chloride	2904	2732	2658	2490	6
Synthetic rubber	1035	1026	1007	988	1
Nitrogen fertilizers[c]	1674[g]	1634[g]	1826[h]	1843[h]	2
Phosphate fertilizers[b]	na	311	394	473	—

a C&EN Estimates. b As P_2O_5. c As N. d Manufacturers' sales. e From petroleum refining and coal processing. f From petroleum refining only. g Excludes calcium cyanamid fertilizers. h Includes calcium cyanamide fertilizers. na = not available. **Sources:** Government agencies for each country

COMPANY RESULTS: Profitability continued to improve for most European chemical producers

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
BASF (West Germany)						
1987	$22,354.4	$ 583.9	2.6%	$1532.2	$ 896.1	133.8
1986	18,650.2	419.4	2.2	1224.4	704.1	131.5
1985	15,094.2	339.5	2.2	950.3	488.1	130.2
1984	14,175.4	314.0	2.2	719.6	435.8	115.8
Bayer (West Germany)						
1987[a]	$20,635.0	$ 857.8	4.2%	$1425.0	$1276.7	164.4
1986[a]	17,642.4	624.0	3.5	1109.7	994.9	164.1
1985	15,621.1	488.4	3.1	700.0	725.9	176.1
1984	15,098.9	411.9	2.7	646.3	686.3	174.8
Hoechst (West Germany)						
1987[a]	$20,531.1	$ 848.9	4.1%	$1330.0	$1231.7	167.8
1986[a]	15,313.8	606.9	4.0	949.8	918.0	153.7
1985	14,531.3	499.3	3.4	804.4	708.5	180.6
1984	14,546.3	474.4	3.3	724.9	637.9	177.9
ICI (U.K.)						
1987	$18,234.4	$1245.9	6.8%	$1160.7	$ 755.7	127.8
1986	14,862.2	879.8[b]	5.9	942.8	573.3	121.8
1985	13,892.5	715.0[c]	5.1	821.2	452.1	118.6
1984	13,247.3	608.8[d]	6.1	589.6	399.7	115.6
Montedison (Italy)						
1987	$10,641.2	$ 436.7	4.1%	$ 786.3	$ 290.9	66.8
1986	8,607.6	(46.1)[e,f]	—	570.8	207.9	66.6
1985	7,402.8	126.3[g]	1.7	342.6	157.2	69.7
1984	7,047.2	(14.8)[e,h]	—	279.5	142.3	71.2
Ciba-Geigy (Switzerland)						
1987	$10,579.9	$ 738.3	7.0%	$ 918.1	$1122.8	86.1
1986	8,863.9	645.0	7.3	684.4	903.9	82.2
1985	7,406.9	598.4	8.1	493.1	680.5	81.0
1984	7,435.7	505.1	6.8	428.5	619.6	81.4
Rhône-Poulenc (France)						
1987	$ 9,344.4	$ 392.7	4.2%	$ 830.4	$ 585.2	83.0
1986	7,603.8	289.8	3.8	732.5	426.3	78.0
1985	6,240.5	257.1	4.1	460.5	317.6	78.0
1984	5,858.4	227.6	3.9	395.2	281.7	80.0
Norsk Hydro (Norway)						
1987	$ 8,086.5	$ 271.5	3.4%	$1451.0	$ 97.2	39.1
1986	7,085.3	(50.6)[e]	—	1562.7	81.2	43.1
1985	5,296.0	257.1	4.9	825.0	58.1	26.4
1984	4,910.4	295.6	6.0	651.0	29.5	19.8
Akzo (Netherlands)						
1987	$ 7,652.7	$ 354.8[i]	4.6%	$ 539.4	$ 399.5	67.4
1986	6,373.5	366.5[j]	5.7	451.4	304.5	68.4
1985	5,424.7	275.1[k]	5.1	303.6	218.4	65.0
1984	5,146.4	252.0[l]	4.9	244.2	198.8	66.1

$ Millions	Net sales	Net income	Profit margin	Capital spending	R&D spending	Employees (thousands)
Sandoz (Switzerland)						
1987	$ 6,026.2	$420.8	7.0%	$421.5	$540.3	44.0
1986	4,645.0	300.6	6.5	306.1	414.4	42.6
1985	3,436.2	215.0	6.3	169.9	294.7	40.2
1984	3,163.4	174.9	5.5	129.4	269.8	38.0
Solvay (Belgium)						
1987	$ 5,989.9	$325.9[m]	5.4%	$498.3	$247.1	45.0
1986	4,842.5	222.3[n]	4.6	517.1	192.6	44.8
1985	3,796.6	187.6[o]	4.9	271.1	131.8	44.5
1984	3,871.5	200.2[p]	5.2	195.6	126.7	43.5
Hoffmann-La Roche (Switzerland)						
1987	$ 5,171.1	$323.5	6.3%	$348.8	$715.8	47.5
1986	4,345.7	231.1	5.3	293.7	623.7	46.5
1985	3,634.3	183.6	5.1	220.2	486.3	45.5
1984	3,519.1	161.8	4.6	214.0	486.2	46.2
DSM (Netherlands)						
1987	$ 4,222.7	$260.6[q]	5.9%	$431.0	$140.4	27.9
1986	3,670.6	198.0[r]	5.4	329.0	91.8	27.3
1985[s]	7,267.8	146.1	2.0	297.6	57.2	26.6
1984[s]	7,018.8	179.6[t]	2.6	285.7	54.5	27.2
BOC International (U.K.)						
1987	$ 3,211.6	$273.4[u]	8.5%	$362.5	$ 61.5	37.5
1986	2,851.3	10.7[v]	0.4	347.4	55.7	37.7
1985	2,462.2	179.1[w]	7.3	312.8	46.2	36.9
1984	2,811.5	153.1[x]	5.4	322.6	56.6	38.7
Fisons (U.K.)						
1987	$ 1,246.4	$139.7[y]	11.2%	$ 6.1	na	10.4
1986	1,030.2	97.7[z]	9.5	10.4	na	10.2
1985	837.7	73.3[aa]	8.8	7.4	$ 22.7	9.0
1984	738.8	50.8[bb]	6.9	9.4	20.1	8.6
Albright & Wilson (U.K.)						
1987	$ 1,065.9	$ 44.8	4.2%	$ 55.6	na	6.4
1986	955.6	33.1	3.5	47.8	na	6.6
1985	832.1	27.8[cc]	3.3	55.7	na	6.8
1984	761.2	29.3[dd]	3.8	46.8	na	6.3
UCB (Belgium)						
1987	$ 874.9	$ 39.3[ee]	4.5%	$ 72.1	$ 38.2	7.4
1986	659.4	31.5[ff]	4.8	40.2	28.7	6.5
1985	524.3	17.0[gg]	3.2	22.9	19.5	6.4
1984	534.8	23.0[hh]	4.3	21.6	18.4	6.5
Laporte Industries (U.K.)						
1987	$ 758.4	$ 80.5[ii]	9.8%	$ 27.9	na	4.2
1986	618.2	60.4[jj]	9.8	33.0	na	4.1
1985	481.0	46.2[kk]	9.6	35.0	na	3.6
1984	475.4	37.3	7.8	13.5	na	3.6

a Excludes companies owned 50% or less. b Excludes nonrecurring loss of $63.0 million. c Excludes nonrecurring loss of $51.8 million. d Excludes nonrecurring loss of $26.7 million. e Net loss. f Excludes nonrecurring gain of $17.6 million. g Excludes nonrecurring minority interests' loss of $68.1 million. h Excludes nonrecurring gain of $17.6 million and minority interests' loss of $50.1 million. i Excludes nonrecurring gain of $134.6 million. j Excludes nonrecurring gain of $9.5 million. k Excludes nonrecurring gain of $0.8 million and minority interests' loss of $22.0 million. l Excludes nonrecurring loss of $10.6 million and minority interests' loss of $6.7 million. m Excludes nonrecurring loss of $90.0 million. n Excludes nonrecurring loss of $83.3 million. o Excludes nonrecurring loss of $50.5 million. p Excludes nonrecurring loss of $60.9 million. q Excludes nonrecurring loss of $40.4 million. r Excludes nonrecurring loss of $22.4 million. s Includes wholly owned DSM-Aardgas for 1984 and 1985. t Excludes nonrecurring gain of $6.3 million and minority interests' loss of $29.1 million. u Excludes nonrecurring loss of $8.2 million. v Excludes nonrecurring loss of $5.0 million and pretax write-off of $187.7 million. w Excludes nonrecurring loss of $4.9 million. x Excludes nonrecurring loss of $23.7 million. y Excludes nonrecurring loss of $8.4 million. z Excludes nonrecurring loss of $7.2 million. aa Excludes nonrecurring loss of $3.7 million. bb Excludes nonrecurring loss of $5.6 million. cc Excludes nonrecurring loss of $10.0 million. dd Excludes nonrecurring loss of $3.5 million. ee Excludes nonrecurring loss of $3.2 million. ff Excludes nonrecurring loss of $2.3 million. gg Excludes nonrecurring loss of $6.2 million. hh Excludes nonrecurring loss of $0.5 million. ii Excludes nonrecurring loss of $1.8 million. jj Excludes nonrecurring gain of $7.8 million. kk Excludes nonrecurring gain of $4.1 million. na = not available.

NOTE ON CURRENCY CONVERSION

For monetary statistics in this section, European currencies were converted to U.S. dollars by the following conversion rates:

	$1.00 (U.S.) is equivalent to:									
	Belgium	France	Italy	Netherlands	Norway	Spain	Sweden	Switzerland	U.K.	West Germany
1987	37.33 francs	6.01 francs	1296 lire	2.03 guilders	6.74 crowns	123.48 pesetas	6.34 crowns	1.49 francs	0.610 pound	1.80 marks
1986	44.67 francs	6.93 francs	1491 lire	2.45 guilders	7.39 crowns	140.05 pesetas	7.14 crowns	1.80 francs	0.682 pound	2.17 marks
1985	59.38 francs	8.99 francs	1909 lire	3.32 guilders	8.60 crowns	170.04 pesetas	8.60 crowns	2.46 francs	0.772 pound	2.94 marks
1984	57.78 francs	8.74 francs	1757 lire	3.21 guilders	8.16 crowns	160.76 pesetas	8.27 crowns	2.35 francs	0.748 pound	2.85 marks
1983	51.13 francs	7.62 francs	1519 lire	2.85 guilders	7.30 crowns	143.43 pesetas	7.67 crowns	2.10 francs	0.659 pound	2.55 marks

Source: International Monetary Fund

6 Foreign Chemical Industries—Japan

Japanese chemical companies didn't let a much stronger yen stop them from scoring higher profits last year. The sharply appreciating yen had the expected impact on trade figures; the percentage growth last year of both chemical exports and imports was much higher measured in U.S. dollars than in yen.

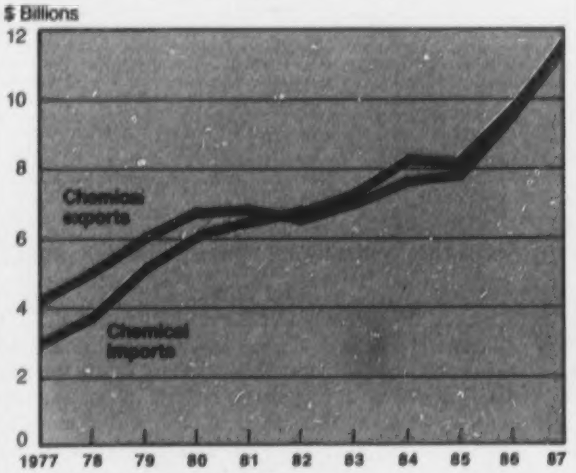
But other fears about the impact of the yen proved ill-founded. The Japanese economy started accelerating in the second half of 1987, with domestic demand more than picking up the slack from lower overall exports. In yen, total Japanese exports have declined for two successive years. But for Japanese chemical companies, strong domestic demand stimulated production last year, leading to higher sales and sharply improved profitability.

INDUSTRY TRENDS: Chemical output higher

Production index, 1980 = 100	1987	1986	1985	1984	Change 1986–87
All manufacturing	126.6	121.7	122.1	116.7	4%
All chemicals	131.3	122.2	121.6	117.9	7
Inorganic chemicals and pigments	114.3	110.0	110.3	105.9	4
Alkalies and chlorine	99.3	94.4	95.9	95.2	5
Organic chemicals	100.9	95.0	95.6	96.9	6
Petrochemicals	123.1	114.6	114.1	113.7	7
Aromatics	119.5	111.9	112.0	106.6	7
Cyclic intermediates and dyes	129.4	118.3	117.0	116.9	9
Plastics	129.2	120.9	119.9	119.7	7
Synthetic fibers	95.3	96.6	100.6	100.2	−1
Synthetic rubber	108.9	105.4	105.8	106.1	3
Fertilizer	69.5	71.5	76.8	79.6	−3
Textile materials	126.7	117.7	115.0	108.0	8
Medicinals and drugs	158.2	143.8	143.0	135.0	10

Source: Ministry of International Trade & Industry

Chemical trade nearly in balance



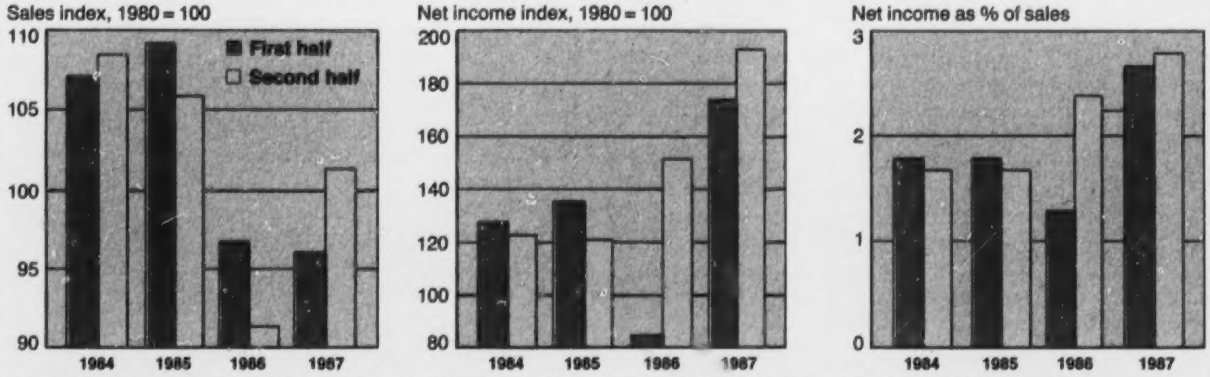
Source: Ministry of International Trade & Industry

PRODUCTION: Solid gains among organics

Thousands of metric tons unless otherwise indicated	1987	1986	1985	1984	Change 1986–87
INORGANIC CHEMICALS					
Ammonia	1784	1794	1981	2029	−1%
Ammonium chloride	332	364	373	387	−9
Ammonium sulfate	1804	1784	1837	1829	1
Calcium carbide	354	399	441	476	−11
Calcium superphosphate	499	514	529	559	−3
Carbon black	629	616	632	606	2
Chlorine, liquid	911	881	926	897	3
Hydrochloric acid	543	549	549	521	−1
Nitrogen, millions of cu m	6452	6293	6220	5896	3
Oxygen, millions of cu m	6878	6786	7388	7216	1
Sodium carbonate	1098	1022	1057	1036	7
Sodium hydroxide	3227	3077	3075	3085	5
Sodium silicate	664	603	594	596	10
Sulfuric acid	6541	6561	6580	6458	0
Titanium dioxide	238	223	217	205	7
ORGANIC CHEMICALS					
Acetaldehyde	285	254	271	297	12
Acetic acid	367	300	344	350	22
Acetone	260	228	237	246	14
Acrylonitrile	573	546	541	523	5
Benzene[a]	2224	2071	2084	2013	7
Butadiene	707	656	639	627	8
Butanol	259	248	258	243	4
Caprolactam	470	448	455	436	5
Cyclohexane	557	515	524	492	8
Dioctyl phthalate	261	257	241	249	2
Ethylene	4585	4291	4224	4390	7
Ethylene dichloride	2051	1908	1901	1939	7
Ethylene glycol	313	339	440	429	−8
Ethylene oxide	484	489	554	533	−1
Methanol	181	221	254	280	−18
Octanol	257	235	230	246	9
Phenol	308	260	262	272	18
Phthalic anhydride[a]	172	163	162	156	6
Propylene	3370	3167	2980	2981	6
Propylene glycol	236	223	219	205	6
Styrene	1559	1417	1418	1423	10
Terephthalic acid	1047	935	854	742	12
Toluene	882	805	803	784	9
Toluene diisocyanate	91	86	84	76	6
Urea	1767	1570	929	1120	13
Xylene	729	778	1523	1401	−6
PLASTICS					
Phenolic resins	332	313	325	334	6
Polyethylene	2182	2066	2027	2251	6
Polypropylene	1406	1333	1304	1271	5
Polystyrene	1735	1598	1599	1503	9
Polyvinyl chloride	1663	1540	1550	1504	8
SYNTHETIC RUBBER	1192	1150	1158	1160	4

a Petroleum-based product only. Source: Ministry of International Trade & Industry

Chemical sales recovered a bit, but profits soared, sharply improving profit margins



Note: Based on results of 12 leading Japanese chemical companies: Asahi Chemical Industry, Dainippon Ink & Chemicals, Hitachi Chemical, Mitsubishi Kasei, Mitsubishi Petrochemical, Mitsui Toatsu Chemicals, Sekisui Chemical, Showa Denko, Sumitomo Chemical, Takeda Chemical Industries, Teijin, and Toray Industries. The fiscal year for most, but not all, of these companies ends March 31. **Source:** Toyo Keizai Shinposha

COMPANY RESULTS: **Profitability widened markedly for several chemical firms in the past year**

$ Millions	Sales	Net income	Profit margin	Total assets	Employees (thousands)
Asahi Chemical Industry[a]					
1987	$5357	$141.0	2.6%	$5241	15.6
1986	4351	84.6	1.9	4361	15.9
1985	3910	73.3	1.9	3661	15.9
1984	3129	57.3	1.8	3027	15.9
Mitsubishi Kasei[b]					
1987	$4360	$ 90.4	2.1%	$6002	8.9
1986	3775	42.0	1.1	5014	8.5
1985	3963	33.1	0.8	4016	8.2
1984	3271	7.0	0.2	3211	8.3
Toray Industries[a]					
1987	$3789	$113.5	3.0%	$4854	10.6
1986	3250	67.1	2.1	3947	11.7
1985	3177	78.2	2.5	3326	12.6
1984	2563	61.4	2.4	2663	13.2
Takeda Chemical Industries[a]					
1987	$3777	$219.6	5.8%	$4628	10.8
1986	2951	133.6	4.5	3599	10.8
1985	2331	98.4	4.2	2612	11.0
1984	1939	75.5	3.9	2246	11.1
Sumitomo Chemical[c]					
1987	$3609	$ 78.6	2.2%	$4615	7.7
1986	3085	29.3	1.0	3949	7.6
1985	3219	38.9	1.2	3277	7.1
1984	2876	58.4	2.0	2818	6.9
Sekisui Chemical[a]					
1987	$3089	$ 84.6	2.7%	$2555	5.3
1986	2229	31.0	1.4	1782	6.3
1985	1769	22.5	1.3	1439	6.2
1984	1415	16.9	1.2	1184	6.1
Dainippon Ink & Chemicals[a]					
1987	$2923	$ 43.7	1.5%	$3366	6.6
1986	2336	32.8	1.4	2214	6.3
1985	2102	26.4	1.3	1722	6.2
1984	1642	20.1	1.2	1449	6.0
Showa Denko[c]					
1987	$2908	$ 38.8	1.3%	$3881	5.0
1986	2116	22.1	1.0	3163	4.8
1985	2066	20.1	1.0	2738	4.6
1984	1683	0.5	0.0	2069	4.6
Mitsui Toatsu Chemical[a]					
1987	$2543	$ 43.5	1.7%	$3004	5.6
1986	2110	23.0	1.1	2599	5.6
1985	2102	14.7	0.7	2242	5.4
1984	1672	8.6	0.5	1810	5.3
Teijin[a]					
1987	$2167	$109.3	5.0%	$3391	6.2
1986	2039	72.0	3.5	2600	6.4
1985	2102	70.9	3.4	2210	7.0
1984	1766	57.3	3.2	1842	7.2
Mitsubishi Petrochemical[c]					
1987	$2022	$ 64.7	3.2%	$2843	2.8
1986	1642	25.7	1.6	2073	2.5
1985	2139	22.4	1.1	1939	2.4
1984	1592	43.3	2.7	1553	2.3
Hitachi Chemical[a]					
1987	$1748	$ 20.7	1.2%	$1056	4.9
1986	1387	14.1	1.0	891	5.0
1985	1123	9.3	0.8	720	4.9
1984	918	13.8	1.5	571	4.8

Note: Monetary statistics are converted from yen to U.S. dollars on the basis of $1.00 equals: 1987, 142.9 Y; 1986, 166.9 Y; 1985, 204.6 Y; 1984, 244.6 Y. Year-to-year changes in sales, net income, and assets are affected by these fluctuations in the currency exchange rate. **a** Fiscal year ends March 31. **b** Fiscal year ends Jan. 31. **c** Fiscal year ends Dec. 31. **Source:** Toyo Keizai Shinposha

6 Foreign Chemical Industries—Canada

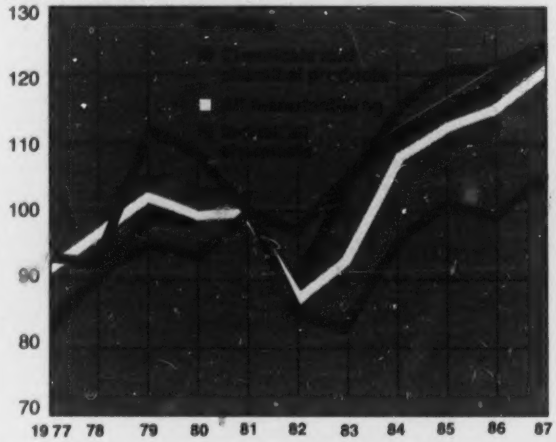
The Canadian chemical industry can find little if anything to complain about in its performance last year. For most Canadian chemical companies, 1987 was a very good year. Strong demand for many products, together with higher selling prices, boosted earnings far above early estimates and widened profit margins markedly. For some companies, sales and earnings set new records.

As usual, ethylene derivatives, especially plastics, spearheaded the advance—in production, in sales, and in chemical exports. And some other chemicals that had been in the marketing doldrums in 1986 bounced back last year. Methanol is one example. Even the long-depressed fertilizer industry showed some signs of improvement in 1987.

Note on currency conversion: Monetary statistics in this section have been converted from Canadian dollars to U.S. dollars on the basis of $1.00 U.S. equals: 1987, $1.322 Canadian; 1986, $1.391 Canadian; 1985, $1.362 Canadian; 1984, $1.308 Canadian; 1983, $1.244 Canadian; 1982, $1.229 Canadian.

Chemical production higher in Canada

Index of volume,[a] 1971 = 100



a Gross domestic product. **Source:** Statistics Canada

COMPANY RESULTS: Profits soared in 1987

$ Millions (U.S.)	Sales	Net income[a]	Profit margin	Capital expenditures	Employees (thousands)
C-I-L Inc.					
1987	$1013.0	$ 30.2	3.0%	$37.8	5.8
1986	927.5	14.4	1.6	38.1	5.6
1985	927.8	28.6	3.1	86.6	6.3
1984	899.6	29.1	3.2	90.5	6.3
Celanese Canada					
1987	$ 265.5	$ 21.5	8.1%	$16.1	2.1
1986	248.2	13.5	5.5	9.0	2.1
1985	247.7	9.3	3.7	11.2	2.1
1984	263.2	4.7	1.8	9.4	2.8
Du Pont Canada					
1987	$1021.4	$ 68.5	6.7%	$47.9	4.2
1986	893.7	43.4	4.9	67.9	4.6
1985	870.7	15.1	1.7	52.4	4.9
1984	895.5	31.5	3.5	34.6	5.0
Polysar Energy & Chemical					
1987[b]	$1855.7	$106.8	5.8%	$53.4	na
1986[c]	1463.2	13.4	0.9	60.8	6.5
1985[c]	1371.1	0.1	—	42.8	6.7
1984[c]	1083.4	27.5	2.5	43.8	6.0
Union Carbide Canada					
1987	$ 318.4	$ 19.4	6.1%	$26.2	2.3
1986	258.1	14.5	5.6	29.7	3.3
1985	254.8	11.7	4.4	16.4	3.8
1984	300.3	9.0	3.0	15.0	4.1

a Excludes extraordinary gains and losses. b Petrochemical operations only. c Data for Polysar Ltd.

PRODUCTION: Growth for organics, plastics

Thousands of metric tons	1987	1986	1985	1984	Change 1986–87
INORGANIC CHEMICALS					
Ammonia	3512	3540	3620	3493	−1%
Ammonium nitrate	844	948	1075	1035	−11
Ammonium phosphate	941	1149	1301	1383	−18
Carbon black	249	154	173	177	67
Chlorine	1635	1536	1424	1424	6
Hydrochloric acid	164	153	158	161	7
Nitric acid	900	1024	1128	1100	−12
Phosphoric acid, 100% P_2O_5	464	554	629	691	−16
Sodium chlorate	432	373	336	313	16
Sodium hydroxide	1770	1696	1589	1574	4
Sulfuric acid	3437	3536	3890	4043	−3
Zinc oxide	44	38	na	31	15
ORGANIC CHEMICALS					
Acetone	na	na	23	25	—
Benzene	720	635	691	549	13
Butadiene	167	146	132	127	14
Butylene	156	142	133	129	10
Ethylene	2140	1909	1745	1464	12
Formaldehyde	122	117	na	97	4
Methanol	1627	1403	na	1872	16
Propylene	628	628	647	656	0
Toluene	396	393	472	395	1
Urea	2142	2330	2033	2162	−8
Xylenes	345	356	415	406	−3
PLASTICS					
Polyethylene, low density	1021	887	733	529	15
Polyethylene, high density	269	242	229	227	11
Polyethylene, total	1291	1129	962	755	14
Polystyrene[a]	197	186	178	171	6
Polyesters, unsaturated	47	37	36	34	27

a Includes acrylonitrile-butadiene-styrene resins. na = not available. **Source:** Statistics Canada

SHIPMENTS: Dollar volume climbed more than 10% in most product areas

$ Millions (U.S.)	1987	1986	1985	1984	1983	1982
All manufacturing	$197,811	$179,420	$179,177	$174,373	$163,192	$152,551
Chemicals and chemical products	14,526	13,066	12,898	12,821	12,613	11,573
Industrial chemicals, inorganic	1,818	1,651	1,605	1,757	1,750	1,702
Industrial chemicals, organic	3,321	2,725	2,833	2,966	3,102	2,947
Plastics and synthetic resins	1,621	1,396	1,317	1,331	1,302	1,126
Pharmaceuticals and medicinals	1,944	1,664	1,536	1,468	1,336	1,187
Adhesives	123	111	98	94	92	64
Paint and varnish	1,125	951	881	815	784	667
Soaps and cleansers	1,023	1,038	1,028	962	940	902
Toilet preparations	751	640	626	614	597	542
Printing ink	214	209	184	183	172	149
Miscellaneous	1,474	1,325	1,292	1,258	1,274	1,317
Synthetic fibers	691	586	563	568	607	485
Plastic products	3,394	2,890	2,700	2,633	2,448	2,183

Source: Statistics Canada

CHEMICAL IMPORTS: 12% higher in 1987

$ Millions (U.S.)	1987	1986	1985	1984
Inorganic chemicals	$ 397	$ 378	$ 374	$ 381
Organic chemicals	1270	1162	1107	1120
Fertilizers and fertilizer materials	157	143	152	158
Synthetic and reclaimed rubber	202	169	160	158
Plastic materials	831	702	651	644
Plastic film and sheet	373	306	278	253
Other plastic shapes and forms	262	233	214	202
Dyes, except dyeing intermediates	71	58	49	56
Pigments, lakes, and toners	114	94	78	77
Paints and related products	176	133	127	113
Other chemical products	859	820	807	824
TOTAL	**$4712**	**$4138**	**$3997**	**$3986**
Imports from U.S.	**$3586**	**$3145**	**$3034**	**$3114**
U.S. share	**76%**	**75%**	**76%**	**78%**

Source: Statistics Canada

CHEMICAL EXPORTS: U.S. share down

$ Millions (U.S.)	1987	1986	1985	1984
Chemical elements	$ 167	$ 173	$ 158	$ 174
Other inorganic chemicals	907	881	828	797
Organic chemicals	1027	882	995	992
Fertilizers and fertilizer materials	960	835	946	1171
Synthetic rubber and plastic materials	854	631	587	481
Plastics, basic shapes and forms	379	327	238	203
Other chemical products	336	291	236	236
TOTAL	**$4629**	**$3961**	**$3988**	**$4054**
Exports to U.S.	**$2938**	**$2625**	**$2669**	**$2663**
U.S. share	**63%**	**67%**	**67%**	**66%**

Source: Statistics Canada

TRADE BALANCE: Surplus increased slightly

$ Billions (U.S.)	1987	1986	1985	1984	1983
Total exports	$91.8	$83.8	$85.3	$83.8	$71.1
Total imports	88.0	81.3	77.1	73.2	60.8
Trade balance	3.8	2.5	8.2	10.6	10.3

Chemical trade deficit narrowed

$ Millions (U.S.)	1987	1986	1985	1984	1983
Chemical exports	$4629	$3961	$3988	$4054	$3487
Chemical imports	4712	4198	3997	3986	3531
Chemical trade balance	−83	−237	−9	68	−44

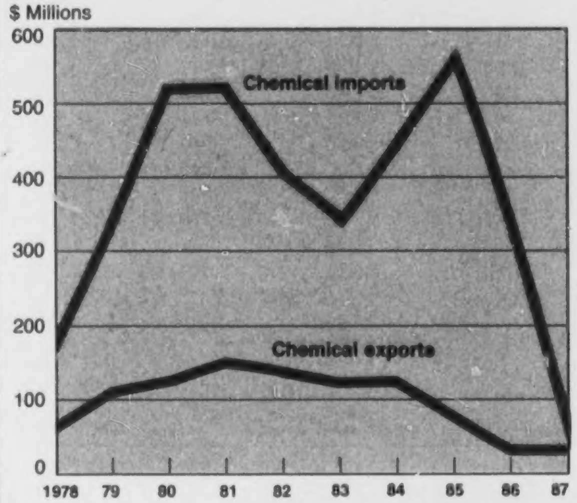
Source: Statistics Canada

PRICES: Increases largest for plastics, drugs

Price index, 1981 = 100	1987	1986	1985	Change 1986-87
All commodities	122.8	119.6	118.6	3%
Chemicals and chemical products	119.6	116.1	114.5	3
Inorganic industrial chemicals	111.6	113.5	114.5	−2
Sulfuric acid	130.6	125.2	121.7	4
Chlorine	130.4	128.5	130.1	1
Organic industrial chemicals	94.9	90.2	94.5	5
Benzene-toluene-xylene	70.1	68.5	94.0	2
Olefins	79.5	76.9	83.5	3
Synthetic resins	117.8	110.4	109.4	7
Polyethylene[a]	105.6	96.5	90.8	9
Polystyrene	122.7	93.9	93.6	31
Thermosets	116.2	108.3	115.1	7
Synthetic fibers	101.7	100.1	101.2	2
Pharmaceuticals	160.3	150.0	141.5	7
Paint and varnish	130.2	129.4	121.6	1
Soaps and cleansers	127.6	123.4	119.1	3
Toilet preparations	152.1	146.3	140.9	4
Agricultural chemicals	118.8	111.4	111.9	1
Pigments, lakes, and toners	120.7	119.6	115.0	1
Mixed fertilizers	97.9	97.2	100.4	1
Inks	110.7	111.4	110.4	−1

[a] Includes both high and low density. **Source:** Statistics Canada

Pemex's petrochemical trade has dwindled



Note: Trade by Pemex of primary petrochemicals only. Does not include secondary chemicals. 1987 import statistics reflect the fact that private companies, as well as Pemex, can now import primary petrochemicals directly. **Source:** Petróleos Mexicanos

CHEMICAL IMPORTS: Pemex has cut many

Thousands of metric tons[a]	1987	1986	1985	1984	Change 1986–87
Acetaldehyde	0	26	70	70	—
Acrylonitrile	0	36	50	34	—
Ammonia	151	13	39	0	1070%
Butadiene	0	44	97	67	—
Cyclohexane	0	19	33	26	—
Dichloroethane	0	0	0	57	—
Dodecylbenzene	0	5	39	49	—
Ethylbenzene	3	0	6	16	—
Ethylene oxide	0	2	48	11	—
Isopropyl alcohol	0	26	50	44	—
Perchloroethylene	0	15	14	15	—
Polyethylene, high density	1	82	42	19	−99
Polyethylene, low density	1	76	127	63	−99
Propylene	22	26	26	26	−16
Propylene tetramer	6	47	19	12	−87
Styrene	0	49	112	93	—
Toluene	0	47	43	37	—
Vinyl chloride	0	100	162	109	—
***p*-Xylene**	0	7	9	0	—
***p*-Xylene**	0	114	179	119	—

[a] Imports by Petróleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

DOMESTIC SALES: Slump continued

Thousands of metric tons[a]	1987	1986	1985	1984	Change 1986–87
Acetaldehyde	157	150	199	212	5%
Acrylonitrile	58	91	96	84	−36
Ammonia, anhydrous	1909	1857	1804	1670	3
Benzene	14	13	17	12	7
Butadiene	18	68	110	106	−73
Cyclohexane	51	55	62	50	−8
Dodecylbenzene	92	102	100	101	−10
Ethylene oxide	94	109	118	112	−14
Hexane	48	37	48	50	28
Isopropyl alcohol	16	42	61	58	−62
Methanol	160	176	176	162	−9
Polyethylene, high density	78	119	134	136	−34
Polyethylene, low density	296	282	266	222	5
Styrene	119	123	140	125	−3
Sulfur	497	462	457	455	8
Toluene	77	90	97	85	−15
Vinyl chloride	173	261	275	259	−34
***o*-Xylene**	63	43	38	32	46
***p*-Xylene**	203	226	268	263	−10

[a] Domestic sales by Petróleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

PRODUCTION: Some petrochemicals surge

Thousands of metric tons[a]	1987	1986	1985	1984	Change 1986–87
Acetaldehyde	158	136	145	147	16%
Acrylonitrile	58	54	49	49	8
Ammonia, anhydrous	2121	1949	2261	2156	9
Benzene	282	222	178	156	27
Butadiene	21	18	18	20	18
Cyclohexane	52	39	32	30	32
Cumene	38	42	39	33	−10
Dichloroethane	326	271	193	220	20
Dodecylbenzene	98	103	61	51	−5
Ethane	2518	2550	1905	1574	−1
Ethylbenzene	152	91	46	31	67
Ethylene	804	767	670	643	5
Ethylene oxide	95	114	71	97	−16
Hexane	98	101	98	95	−3
Hydrochloric acid	117	83	63	77	41
Isopropyl alcohol	17	11	14	14	52
Methanol	191	182	192	197	5
Nitrogen	49	49	46	47	0
Oxygen	179	206	211	200	−13
Polyethylene, high density	76	69	67	76	10
Polyethylene, low density	275	242	160	134	14
Propylene	257	232	207	208	11
Propylene tetramer	76	51	31	35	48
Styrene	121	69	33	30	74
Sulfur, recovered	501	456	475	461	10
Toluene	313	238	220	216	32
Vinyl chloride	179	141	108	132	27
***m*- and *p*-Xylene**	313	231	247	225	35
***o*-Xylene**	68	42	44	43	64

[a] Production by Petróleos Mexicanos (Pemex) of primary petrochemicals. **Source:** Pemex

PRODUCTION GROWTH: Slower in 1987 for most East European nations

% annual change in gross output	1987	1986	1985	1984	1983
U.S.S.R. and East Europe					
All industry	3.7%	4.8%	3.9%	4.3%	4.3%
Bulgaria					
All industry	3.3	4.0	3.2	4.2	4.3
Chemicals	1.3	4.9	3.6	8.2	5.9
Czechoslovakia					
All industry	2.3	3.2	3.5	4.0	2.8
Chemicals	na	4.0	5.1	4.5	3.3
East Germany					
All industry[a]	3.7	3.7	4.4	4.2	4.1
Chemicals	2.5	2.2	3.7	4.3	2.9
Hungary					
All industry	3.7	1.9	0.7	3.2	1.2
Chemicals[b]	6.2	1.3	0.8	4.4	1.6
Poland					
All industry	3.3%	4.7%	4.5%	5.2%	6.4%
Chemicals	5.2	4.2	3.0	5.0	8.2
Romania					
All industry	4.5	7.7	4.8	6.7	4.7
Chemicals	na	8.3	0.3	8.1	5.4
U.S.S.R.					
All industry[c]	3.8	4.9	3.9	4.1	4.2
Chemicals[c]	3.2	6.3	5.0	5.1	5.9
All industry[d]	na	3.6[e]	2.7	2.6	2.7
Chemicals[d]	na	4.4[e]	4.3	3.4	5.8

a Industrial commodity production. b For state and cooperative industry only. c Figures based on official Soviet statistics. d Figures based on Central Intelligence Agency estimates, giving lower results because of postulated upward bias in official figures. e Preliminary figure. na = not available. **Sources:** United Nations Economic Commission for Europe and state central statistical bureaus, Central Intelligence Agency

PRODUCTION: Increases were modest during mid-1980s for several big-volume chemicals

Thousands of metric tons, unless otherwise noted	1987[a]	1986	1985	1984	1983
U.S.S.R.					
Sulfuric acid	28,500	27,847	26,037	25,338	24,714
Mineral fertilizers[b]	36,300	34,739	33,194	30,808	29,733
Nitrogen[b]	15,900	15,221	14,223	13,328	13,014
Phosphate[b,c]	9,601	9,279	8,596	7,695	7,417
Potassium[b]	10,790	10,228	10,367	9,776	9,294
Synthetic ammonia[d]	na	19,590	18,232	17,677	16,904
Plastics[e]	5,500	5,345	5,019	4,819	4,419
Sodium hydroxide	3,300	3,229	3,056	2,972	2,853
Ethylene	na	2,799	2,667	2,543	2,267
Methanol	na	3,219	2,850	2,467	2,174
Synthetic rubber[f]	na	2,250	2,125	2,085	1,970
Pesticides[g]	327	332	346	343	332
BULGARIA					
Sulfuric acid	na	807	810	908	861
Mineral fertilizers[b]	na	580	640	690	687
Nitrogen[b]	na	448	469	479	483
Phosphate[b]	na	132	172	211	204
Synthetic ammonia[d]	na	1,091	1,138	1,138	1,124
Plastics	na	420	393	430	398
Sodium hydroxide	na	138	151	163	147
Synthetic rubber	na	26	26	26	25
Pesticides[g]	na	15	18	20	21
CZECHOSLOVAKIA					
Sulfuric acid	1,264	1,292	1,297	1,246	1,244
Mineral fertilizers[b]	na	1,041	1,204	1,190	1,175
Nitrogen[b]	596	614	582	576	591
Phosphate[b,c]	277	307	407	398	378
Potassium[b,g]	na	120	215	216	206
Synthetic ammonia[d]	na	930	994	827	809
Plastics	1,152	1,140	1,103	1,039	1,002
Sodium hydroxide	na	335	331	329	330
Synthetic rubber	na	76	70	71	67
Pesticides[g]	na	20	19	17	16
EAST GERMANY					
Sulfuric acid	na	883	883	885	926
Mineral fertilizers[b]	5,100	5,046	4,843	4,732	4,714
Nitrogen[b]	1,300	1,252	1,078	959	968
Phosphate[b,c]	300	309	299	308	315
Potassium[b]	3,500	3,485	3,465	3,465	3,431
Synthetic ammonia[d]	na	1197	1210	1207	1210
Plastics	na	1045	1048	1056	1045
Sodium hydroxide	na	638	667	694	687
Synthetic rubber	na	130	140	152	155
Pesticides[g]	na	62	60	58	54
HUNGARY					
Sulfuric acid	na	556	541	549	606
Mineral fertilizers[b]	1064	1040	1066	1100	1110
Nitrogen[b]	na	655	684	675	685
Phosphate[b]	na	267	252	286	285
Potassium[b,h]	na	118	130	139	140
Synthetic ammonia[d]	na	762	790	813	812
Plastics	na	423	389	385	345
Ethylene	270	269	271	265	261
Sodium hydroxide[i]	197	202	194	194	192
POLAND					
Sulfuric acid	3147	2966	2863	2769	2786
Mineral fertilizers[b]	na	2526	2270	2356	2324
Nitrogen[b]	1543	1445	1254	1369	1341
Phosphate[b]	943	948	889	869	872
Potassium[b,h]	na	133	127	118	111
Synthetic ammonia[d]	na	1747	1490	1499	1430
Plastics	639	632	603	601	535
Sodium hydroxide	425	427	414	379	392
Ethylene	na	279	261	256	198
Synthetic rubber	117	116	126	119	120
ROMANIA					
Sulfuric acid	na	1971	1835	1915	1941
Mineral fertilizers[b]	na	3278	3097	3073	2913
Nitrogen[b]	na	2315	2197	2212	2091
Phosphate[b]	na	849	788	765	733
Synthetic ammonia[d]	na	3037	2876	2857	2723
Plastics	na	664	628	655	633
Sodium hydroxide	na	846	814	805	745
Ethylene	na	312	307	317	316
Synthetic rubber	na	173	156	159	147
Pesticides[g]	na	53	53	53	48

a Approximate figures or estimates. b Nutrient content basis, as N, P_2O_5, or K_2O. c Including production of ground phosphate rock for direct applications and phosphate animal feeds. d Nitrogen content. e Including resins for man-made fibers. f Estimated. g On basis of active substance. h Imported potash added to domestically produced nitrogen and phosphate to form multinutrient fertilizer. i Including regenerated NaOH. na = not available. **Sources:** Central Intelligence Agency, Department of Agriculture, official national statistics from state central statistical bureaus

CHINA

PRODUCTION: Strong growth in 1987 for most chemical products

Thousands of metric tons, unless otherwise noted	1987	1986	1985	1984	Change 1986–87
Fertilizer[a]	17,033	14,258	13,222	14,602	20%
Synthetic ammonia	19,486	17,195	17,212	18,374	13
Sulfuric acid	9,620	7,510	6,764	8,172	28
Sodium hydroxide	2,735	2,458	2,347	2,222	11
Sodium carbonate	2,372	2,150	2,011	1,880	10
Plastics	1,571	1,283	1,208	1,180	22%

Thousands of metric tons, unless otherwise noted	1987	1986	1985	1984	Change 1986–87
Man-made fibers	1,157	1,016	945	735	14%
Synthetic detergents	1,190	1,150	1,005	810	3
Ethylene	839	642	651	648	31
Pesticides	260	223	211	299	17
Pharmaceuticals	154	107	58	54	44
Rubber tires[b]	24,478	19,932	18,527	15,690	23

a Nutrient content. b In thousands of units, not including wheelbarrow and bicycle tires. na = not available. **Sources:** State Statistical Bureau of the People's Republic of China, *China Daily*

CHEMICAL IMPORTS: Rebounded last year

$ Millions[a]	1987	1986	1985	Change 1986–87
Organic chemicals	$ 999	$ 781	$ 698	28%
Inorganic chemicals	423	330	321	28
Dyeing, tanning, coloring materials	203	158	141	28
Medicinal and pharmaceutical products	229	149	103	54
Fertilizers[b]	1403	678	1481	107
Plastic materials, resins, cellulose esters and ethers	1472	1216	1449	21
TOTAL	**$5019**	**$3533**	**$4476**	**42%**

Note: Monetary statistics are converted from Rmb to U.S. dollars on the basis of $1.00 equals: 1987, 3.72 Y; 1986, 3.72 Y; 1985, 3.2 Y. a Includes cost, insurance, and freight. b Manufactured. **Source:** General Administration of Customs of the People's Republic of China

CHEMICAL EXPORTS: Up sharply

$ Millions[a]	1987	1986	1985	Change 1986–87
Organic chemicals	$ 501	$ 386	$ 314	30%
Inorganic chemicals	554	357	291	55
Dyeing, tanning, coloring materials	176	117	78	50
Medicinal and pharmaceutical products	409	317	302	29
Essential oils, perfumes, cleansing materials	137	102	111	34
Explosives, pyrotechnic products	183	144	114	27
TOTAL	**$2238**	**$1629**	**$1377**	**37%**

a Free on board. **Source:** General Administration of Customs of the People's Republic of China

SOUTH KOREA

INDUSTRY TRENDS: Growth remained good

Index, 1980 = 100	1987	1986	1985	1984	Change 1986–87
Chemicals, petroleum, coal, rubber, and plastic products					
Production	179.6	164.7	146.6	140.7	9%
Shipments	164.5	152.5	138.1	132.6	8
Inventories	139.3	139.3	132.4	125.2	0
Industrial chemicals					
Production	163.8	142.6	129.4	126.4	15
Shipments	174.5	156.2	141.5	134.4	12
Inventories	138.7	128.6	137.0	117.3	8
Other chemical products					
Production	210.7	189.7	171.7	160.8	11
Shipments	211.4	186.8	168.6	158.7	13
Inventories	210.8	192.0	183.8	159.3	10
Rubber products					
Production	189.3	184.2	158.1	158.4	3
Shipments	196.1	184.1	158.4	158.2	7
Inventories	133.5	141.9	139.4	138.2	−6
Plastic products					
Production	213.4	173.2	153.6	145.3	23
Shipments	211.4	173.7	154.7	146.1	22
Inventories	162.9	159.5	130.6	139.9	2
All manufacturing					
Production	233.9	199.4	167.1	160.6	17
Shipments	221.3	188.9	160.6	153.6	17
Inventories	159.1	147.7	150.3	138.0	8

Source: Bureau of Statistics of the Korean Economic Planning Board

PRODUCTION: Mostly higher last year

Thousands of metric tons	1987[a]	1986	1985	1984	Change 1986–87
Sulfuric acid, 98%	2039	1898	2028	1975	7%
Complex fertilizers	1968	1863	1944	1861	6
Urea fertilizers	911	812	839	858	12
Ammonia	588	519	538	565	13
Ethylene	576	534	562	526	8
Polyvinyl chloride	451	473	411	344	−5
Polyethylene	469	385	353	317	22
Polyester fibers	373	320	291	265	16
Sodium carbonate	290	264	251	248	10
Sodium hydroxide	254	251	229	215	1
Benzene	351	301	216	171	17

a Preliminary. **Source:** Bureau of Statistics, Korean Economic Planning Board

FOREIGN TRADE: Chemical deficit widened

$ Millions	1987	1986	1985	1984
Exports[a]	$47,281	$34,714	$30,283	$29,245
Imports[b]	41,020	31,584	31,136	30,631
Trade balance	6,261	3,130	−853	−1,386
Chemical exports	1,321	1,068	936	845
Chemical imports	4,595	3,495	2,789	2,709
Chemical trade balance	−3,274	−2,427	−1,853	−1,864

a Free on board. b Includes cost, insurance, freight. **Source:** Korean Office of Customs Administration

A1250-1
6/27/88

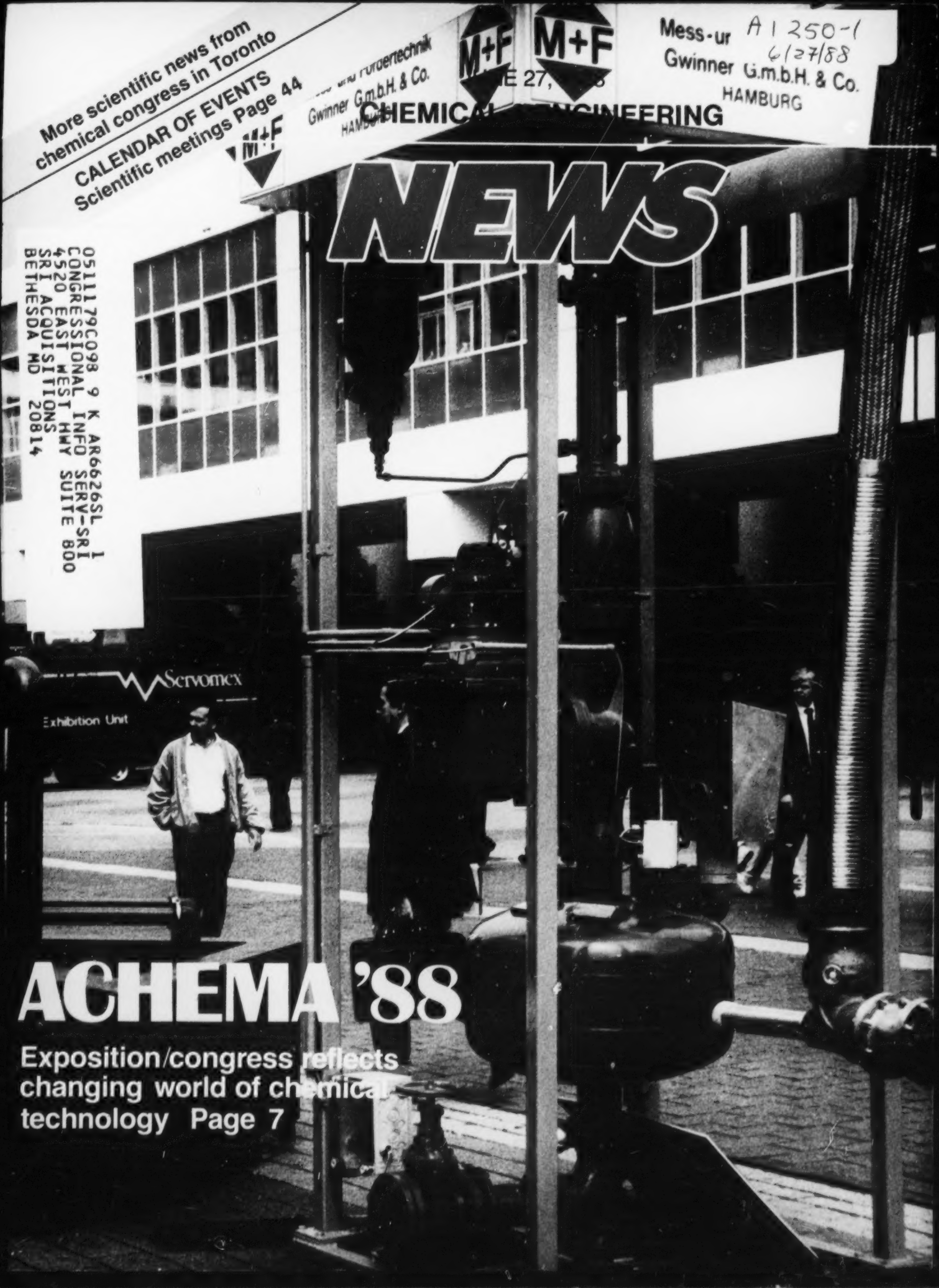
More scientific news from chemical congress in Toronto

CALENDAR OF EVENTS
Scientific meetings Page 44

E 27, 8

CHEMICAL ENGINEERING NEWS

0511179C098 9 K AR6626SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814


M+F
M+F
M+F
Mess-ur
Gwinner G.m.b.H. & Co.
HAMBURG
ss- und Fördertechnik
Gwinner G.m.b.H. & Co.
HAMBURG
Servomex
Exhibition Unit

ACHEMA '88

Exposition/congress reflects changing world of chemical technology Page 7

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 26
CENEAR 66 (26) 1–68
ISSN 0009-2347

JUNE 27, 1988

News of the Week

- **Deciding to go outside India in its legal battle over the Bhopal disaster, Carbide has turned to a Connecticut state court.** Page 4

- **The triennial plastics show, held in Chicago last week, set records for attendance, exhibit space.** Page 5

- **Pennwalt is strenuously trying to head off a takeover bid by Centaur Partners, a group of New York City-based investors.** Page 5

- **Office of Technology Assessment report spells out a number of ways for boosting the pool of science and engineering students.** Page 6

- **European Community is making strong strides toward cutting CFC production and nitrogen oxides and sulfur dioxide emissions.** Page 6

Cover: Photo by C&EN's James H. Krieger

Letters 2
Concentrates
Business 15
Government 21
Science/Technology 26
The Department
Newscripts 68

Business

Free trade with U.S. will benefit Canada's chemical industry; European chemical industry outlook good for 1988. **Page 17**

Government

New trade bill has been introduced in the House; EPA survey shows chemical companies are poorly prepared for chemical emergencies; EPA's management of Superfund program rapped by OTA. **Page 22**

Science

Toronto meeting: Photochemical technique aids understanding of zeolites; impact of computers on chemistry; ICP/MS finding more utility; molecular tweezers; advances in low-cost epoxidation of olefins; design of enzyme inhibitors based on affinity labels; molecular-scale Lego; novel route to arenesulfonates; silicon-29 NMR study of lignins. **Page 27**

Education

More from Toronto: Efforts are under way in Mexico to bolster students' as well as the public's image of chemistry and other sciences. **Page 39**

Technology

From Toronto: Study finds most sulfur dioxide emissions arise from combustion of moderate-coal, not high-sulfur coal. **Page 40**

ACS News

Both the society's board and council met and dealt with ACS issues in Toronto; ACS dues and sections allotments to increase in 1989. **Page 42**

Meetings

C&EN's semiannual calendar lists meetings and other events of interest to chemists and chemical engineers. **Page 44**

News Focus

ACHEMA '88, the chemical engineering exposition and congress held in Frankfurt, West Germany, earlier this month, was a showcase for recent advances in process equipment and state-of-the-art chemical technology. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 67)

LETTERS

Tax burden

SIR: The letter from Pennsylvania State University graduate students Donald Cronce, Susan Ensel, and John Sczepanski (C&EN, April 25, page 3) regarding the 1986 Tax Reform Act prompted me to write of my own concerns in this matter. Last year, when learning that the new tax laws would make graduate student stipends taxable, my fellow students and I at Case Western Reserve University became very concerned over what this could do to higher education in the U.S. We were so concerned, that a letter was penned voicing these concerns and a copy, each individually signed by most of the graduate student population, sent to each of the Congressmen representing Ohio as well as Sen. Glenn and Sen. Metzenbaum. Of the very few responses we received from these gentlemen, most did not seem to realize what "situation" we were writing about, or simply said they "agreed" with us and "would support legislation" to correct the problem. It would seem that graduate students do not have a strong enough lobbying group to merit more attention from our elected officials.

As I have since received my degree, this problem no longer directly affects me, but, as a recent graduate, I can easily commiserate with my fellow students who now have to bear this tax burden. The long-term effects of this situation may be worse than most imagine. Not only will this pose a financial disincentive to those pursuing advanced degrees, the lack of a sufficient number of students will need to be corrected. Most likely this will involve colleges and universities being forced to look overseas in order to fill the demand. This will also create a deficit of American scientists and engineers, forcing industry to look elsewhere for qualified personnel as well. **Sheri L. Blystone**

Oak Ridge National Laboratory

Interesting chemistry

SIR: The letter from David E. Henrie (C&EN, April 25, page 3) should be printed and reprinted until our innovators of freshman chemistry courses take note and realize what is happening.

I agree 100% with Henrie, and I believe that somewhere along the way we have lost touch with reality.

After reading his comments, I read further on to page 20, which told of the amazing life of Carl Marvel. As I was reading, I couldn't resist thinking of what would have happened if he hadn't taken that interesting course in chemistry.

His contributions to World War II technology, his 500 journal articles, his four books, and the 176 students who earned their Ph.Ds. under his tutelage—where would they all be if he had decided to be a farmer?

Why not make the freshman chemistry course interesting and informative instead of all of the theoretical mumble-jumble that will probably never be used? Why not make it so that the students who take these courses will desire to go on further and maybe develop enough interest to become outstanding chemists like Marvel?

But if they don't go any further, at least they will have learned some usable chemistry instead of just wasting their time and everyone else's. **Dan Lange**

St. Louis, Mo.

Environmental health

SIR: The rambling discourse on the perils of modern environmentalism by Fred Tausch Jr. (C&EN, April 18, page 2) is, to say the least, disturbing and extremely misleading. As an individual concerned about this country's environmental health and natural resources, I believe it is necessary to provide a more balanced assessment of the current environmental state-of-affairs.

Tausch's comments reflect the frustrations felt by many Americans when confronted with the facts of pollution and other forms of environmental degradation. The first and most natural human reaction is to ask: Who is to blame? Tausch's answer is simple—the environmentalists. In his search for the perfect scapegoat, Tausch takes the path of least resistance by tapping a highly vocal and visible political community, raising the well-worn (and, in this context, irrelevant) spectre of socialism, and participating in a peculiarly American strain of knee-jerk conservatism. Unfortunately the roots of, and solutions to, our environmental problems are more subtle, complex, and interrelated than anyone ever imagined.

Tausch attempts to characterize environmentalists, all environmentalists, as rabid, regulators-gone-mad, without distinguishing the many ideas and philosophies such a diverse movement may embody. Indeed, this magazine itself could describe many of its readers as environmentalists: concerned individuals, angry at the despoilation of America's natural resources, who desire objective, innovative measures to alleviate

Canada's Chemical Industry To Benefit from Free Trade with U.S.

Trade agreement will help commodity chemicals, but certain segments of the industry, such as specialty chemicals, may face problems

Earl V. Anderson, C&EN New York

Toronto

The Canadian chemical industry is looking forward to doing business under the Canada-U.S. free trade agreement that is worming its way through the legislative process in both countries. But, although the Canadian chemical industry, on balance, likely will benefit from the agreement, some segments of the industry will benefit much more than others.

Some segments, says James E. Sigurdson, will be hurt by the pact, whereas still others will notice little change in the way they operate. Sigurdson, a partner in Law, Sigurdson & Associates, a consulting firm in Toronto, told a session on changing patterns in international trade and regulations just how he thinks free trade will affect the Canadian chemical industry.

Traditionally, that industry has run a chemical balance-of-trade deficit. But largely because of the world-scale petrochemical plants that have been built in Canada over the past decade, that deficit has been declining. Last year, Canada exported $3.78 billion (U.S. dollars) worth of chemicals and imported $4.84 billion worth.

However, among chemicals, Canada is a net exporter only in industrial chemicals. It runs a trade deficit in synthetic resins, for instance, despite its new, world-scale resins plants. Canada also remains a net importer of specialty chemicals and plastics.

The Canadian chemical industry, says Sigurdson, grew up behind a high tariff wall—part of the government's "infant industry" concept of tariff protection. "Several chemical areas still operate happily under that type of protection," he says. However, many petrochemicals and commodity inorganics now are internationally competitive. And on many of these products, there are no tariffs between the two countries.

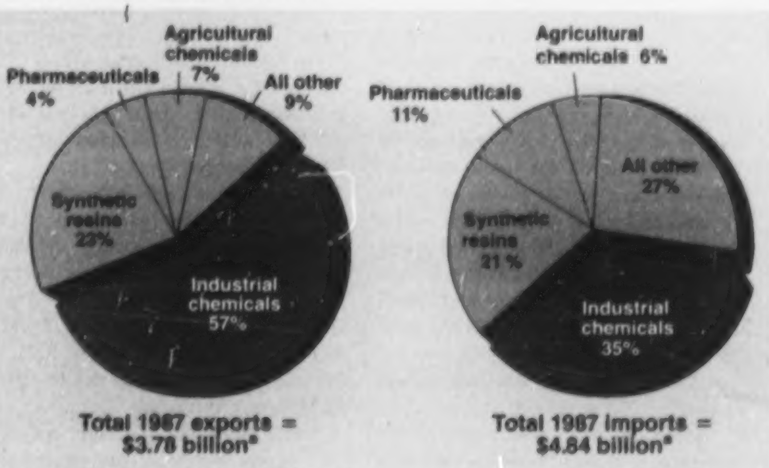
Although the free trade agreement will eliminate tariffs on chemicals over a period of five or 10 years, tariffs aren't really a factor for many chemicals in which Canada has a strong competitive position. Tariffs, Sigurdson says, are a factor only for the small, regional chemical producers in Canada.

He divides Canada's chemical businesses into two groups. One is chemicals that are produced in large, world-scale plants, are competitive, and require export markets to soak up output. The other group contains a variety of all other chemical and plastics products.

The impact of the free trade pact on Canada's fertilizer business will be slight to nil, Sigurdson says. That's because there now are no tariffs on Canadian fertilizer moving into the U.S. Canada produces about $2.7 billion worth of fertilizers and exports just over $1 billion of that output. About 10% of all Canadian chemical exports are fertilizer, and most of it—about 60%—goes to the U.S.

In his analysis of fertilizer trade, Sigurdson includes potash, which is Canada's largest fertilizer export. Official chemical trade figures from

Industrial chemicals account for most of Canadian chemical trade



* U.S. currency; $1.00 = 1.322 Canadian dollars in 1987.
Source: Law, Sigurdson & Associates

Statistics Canada do not include potash. The U.S. is the primary market for other fertilizer products, such as ammonia and nitrogen fertilizers. These products, which account for $378 million in exports, have been hurt for the past several years by the worldwide slump in fertilizers and low farm product prices.

Fertilizer trade, says Sigurdson, tends to be regional. Canadian fertilizer plants in Saskatchewan and Alberta are blessed with low-priced natural gas for their ammonia units. After meeting local demand on the Canadian prairies, producers export their product to the states immediately south of them.

Eastern Canadian fertilizer producers are much smaller and serve the regional markets of New York, Ohio, Pennsylvania, and Michigan. That, says Sigurdson, means that they do not have a market-access problem, although they are more sensitive to competition from other countries than their western counterparts.

Sigurdson also singles out a group of 24 "selected" commodity chemicals in which Canada has a solid competitive position. Substantial volumes of these chemicals are exported, both to the U.S. and to other world markets. They include petrochemicals, which benefit from Canada's inexpensive natural gas, and inorganics, which enjoy low power or raw material costs.

The combined exports of these 24 products add up to $1.6 billion, about half of which moves south of the border. Inorganics exports go primarily to the U.S. and tend to be regional. Organics are exported, not only to the U.S., but to the Pacific Rim and to Europe as well.

U.S. tariffs on these products range from zero to 20%. The higher tariffs are on organics (ethylene dichloride, 20%; methanol, 18%) and, in some cases, do distort trade, says Sigurdson.

However, only in a few instances does he expect the free trade agreement to cause a major shift in trade flow. The $862 million worth of these products exported to the U.S. last year involved duties of only $72 million. Sigurdson says that when the agreement removes these duties, Canadian ethylene dichloride, isopropyl alcohol, ethylene glycol, and a few others in this product group will be the prime beneficiaries.

Petrochemicals are the group's top performers and derive their strength from Alberta's world-scale petrochemical plants. From these plants, styrene, ethylene dichloride, and ethylene glycol are exported to the Pacific Rim countries and to the western U.S. Styrene and isopropyl alcohol are the primary export products of the eastern Canadian petrochemical producers.

Canadian producers of chloralkali, hydrogen peroxide, and sodium chlorate rely on Canada's favorable supply of electricity to be competitive on the continent. Virtually all of these products that are exported go to the U.S., although Sigurdson notes that some sodium chlorate is starting to move offshore.

Canada's inorganics already face little or no tariff barriers in the U.S. The free trade agreement likely will have little impact on them. The trade pattern of some organics could shift, Sigurdson says, as some styrene, methanol, ethylene dichloride, and ethylene glycol going to the Pacific Rim could be diverted to the U.S. market. However, the major impact of the agreement's tariff reductions will be to increase netbacks, particularly on products that now have high tariffs.

Analyzing the agreement's effect on Canada's polymers (plastics and rubbers) exports is more complex. Canada is a strong exporter of plastics resins and synthetic rubber. But it also processes and exports plastics products made from its own resins.

What the Canada-U.S. free trade agreement will do

The Canada-U.S. free trade agreement was signed by the two countries on Jan. 2, but the pact still must make its way through the legislative process of both countries. The target date for implementing the agreement is Jan. 1, 1989.

One of its major provisions calls for eliminating tariffs on trade between the two countries. Tariffs will be eliminated on all goods and services over a maximum period of 10 years. For those sectors that require no adjustment, tariffs will disappear on Jan. 1, 1989, if both countries agree to it. Those sectors that require some adjustment will see their tariffs disappear over a five-year or a 10-year period.

Generally, inorganic commodity chemicals, organic commodities, and synthetic resins fall into the five-year category. It likely will take 10 years to reduce tariffs on specialty chemicals, blended and mixed products, and on plastics products.

The reductions will occur evenly over the period. For instance, if tariffs were to be eliminated over a five-year period, they would be reduced 20% in each of those five years.

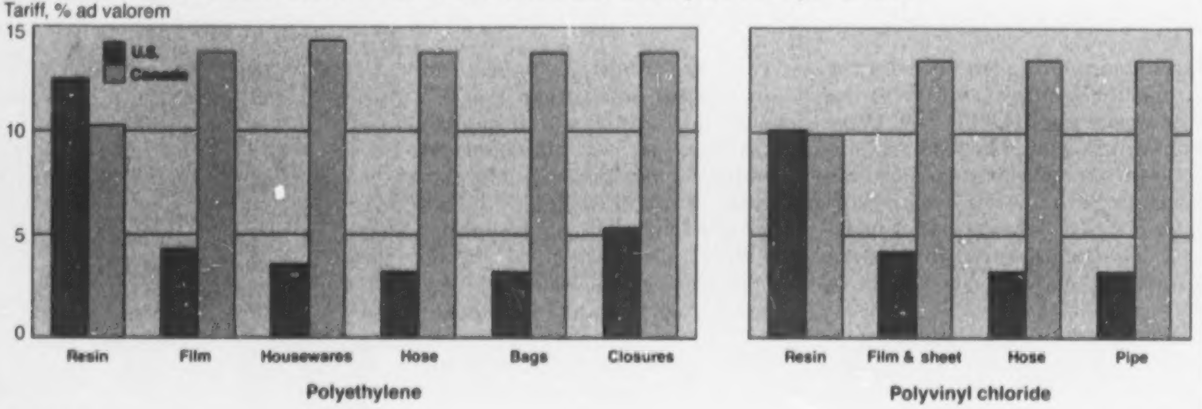
The agreement prohibits both countries from imposing restrictions on the volume or price of products crossing the common border. Another section contains rules of origin. These stipulate that products must contain a minimum of 50% North American (U.S. or Canadian) content in order for their tariffs to be eliminated.

Under the pact, Canada and the U.S. agree that technical regulations should not create unnecessary trade barriers. The two countries also agree to recognize each other's laboratory accreditation systems and eliminate duplication in product testing.

Energy is an important part of the agreement. The agreement prohibits imposing minimum export or import prices on energy. It prohibits imposing taxes on energy exports unless those same taxes are imposed in the domestic market. And it stipulates that any export restrictions must not disrupt normal supply channels.

The pact also covers trade in services. But one of its most contentious provisions calls for a bilateral panel to settle trade disputes between the two countries. Presumably, the panel will ensure that the two countries apply their antidumping and countervailing duty laws impartially.

U.S. tariffs are much lower than Canadian duties on plastics products



Source: Law, Sigurdson & Associates

Total exports of plastics resins and products ran about $1.21 billion last year. However, Canada imported $1.06 billion of resins and $980 million of plastic parts, giving the combined sector a trade deficit of $830 million.

Alberta's petrochemical plants export primarily polyethylene and polyvinyl chloride. Eastern Canadian producers export polyethylene, polypropylene, and Polysar's elastomers. The U.S. is Polysar's major export market for nitrile and butyl rubbers, Sigurdson says, but the other polymers are more oriented toward offshore markets.

Only modest volumes of polyethylene, polypropylene, PVC, and polystyrene are exported to the U.S. The major focus is the Pacific Rim and Europe. Some polypropylene even moves into South America.

At least part of the reason for this, Sigurdson says, are the tariffs facing Canadian polymers exported to the U.S. For the major thermoplastics, they are in the 10 to 12.5% range. Generally, rubber products face no tariffs. Consequently, Canadian rubber plants have, in effect, been part of the North American market for some time, he explains.

Obviously, free trade under the agreement will open up the U.S. market for Canadian thermoplastics. Removing the $27 million that Canadian producers pay in duties will help make them more competitive. And Sigurdson believes that the pact also will cause a significant shift in the export patterns of Canadian resins, with much more earmarked for the U.S.

The best example, Sigurdson says, is polypropylene. Shell Canada Chemical and Himont have a combined annual capacity of 206,000 metric tons of the polymer in eastern Canada. But they export little to the U.S. Removing U.S. tariffs on the polymer will make Canadian polypropylene much more competitive in the U.S.

What complicates the picture for this segment of the Canadian chemical industry is that U.S. tariffs on the major thermoplastic resins are greater than those on the converted products made from them. This has provided a major incentive for Canadian plastics processors to move product into the U.S. "Resin suppliers," Sigurdson says, "have been willing to help in the process," because its more advantageous for them to encourage product exports than try to export resin directly.

Exports of Canadian plastics products have been growing over the past few years, with more than 70% of them going to the U.S. But Canada still has a $430 million trade deficit in this sector, despite the 12 to 15% tariffs that protect Canadian plastics processors. U.S. tariffs on these products, by comparison, range from 3 to 6%.

The Canadian Society of the Plastics Industry has given the free trade agreement only a qualified endorsement, says Sigurdson, because of the "structural problems" facing many of its processor members. Many of them are small and, after operating behind high tariff walls, will face severe competition as Canadian tariff protection is removed under the agreement.

In addition, Sigurdson says, since Canadian resin producers will be able to export their product to the U.S. without duty, they will have less incentive to encourage exports of plastics products to the U.S. This will increase the difficulties likely to face Canadian processors under the agreement.

The net result will be that, over the 10-year phase-in period, Canada's strong, sophisticated processors will do extremely well in the northeastern North American market, says Sigurdson. The weaker ones will find the going tough. And, although Canadian resin exports to the U.S. could double under the free trade pact, the processors in Canada will be more on their own, he says.

Pharmaceuticals, specialty chemicals, paints, and surfactants also will face some tough times under the agreement. Their basic tariff protection will drop and, because their production is centered in eastern Canada, they will have to find market niches in the regional market of northeastern North America.

Sigurdson sees increased petrochemical investment in Alberta as a result of the agreement. There is still more ethane there that can be cracked into ethylene, he says. And as exports of downstream products to the U.S. increase under the pact, more ethylene will be required. ☐

Good year forecast for European chemicals

It was medium-to-good news for the European chemical industry at the annual meeting of CEFIC, the European Council of Chemical Manufacturers' Federations, earlier this month in Berlin. After a weak start to 1987, CEFIC reported, the recovery of chemicals output in Western Europe led to an overall growth of almost 4% for last year.

Domestic European demand was high, and most sectors experienced high capacity utilization. Production was particularly strong in basic petrochemicals, plastics, and consumer-related sectors, but fertilizers and fibers remained weak.

The outlook for 1988 is similarly reassuring. It is expected to be another good year for the chemical industry, with continued firm demand and high levels of production and capacity utilization. Output is forecast to grow some 2.5%, underpinned primarily by European domestic demand. However, the continued weak U.S. dollar will weaken European chemical exports, holding growth to only 4% in volume; imports are expected to grow 5.5%. Capital spending is expected to continue strong, growing at 6% in real terms.

Portugal led output growth in Europe last year

	% change 1986–87 in volume of chemical production
Portugal	14.9%
Sweden	8.7
Ireland	8.2
U.K.	7.4
Spain	7.0
Netherlands	6.9
Austria	5.6
Norway	4.4
Switzerland	3.2
France	3.1
West Germany	2.4
Italy	2.2
Finland	1.4
Belgium/Luxembourg	0.6
Denmark	−1.2
AVERAGE, WESTERN EUROPE	3.9%

Note: Comparisons should be made with caution, because countries' national statistics frequently differ in what is included. For example, some countries include synthetic fibers, plastics, and rubber, while others exclude them. Source: European Council of Chemical Manufacturers' Federations

With the industry's basic condition sound, that gives CEFIC a chance to continue addressing concerns such as environmental protection and health and safety, says Günter Metz, newly elected president of CEFIC and a vice president for West German chemicals producer Hoechst. These issues, he says, "remain the number one concern of CEFIC."

And it is not just a matter of technology: "We cannot just do things in a better way like producing safer products, using cleaner technology, reducing emissions, to mention a few," Metz says. "We must above all gain confidence of the population at large and take even more account of emotional reactions that are often due to ignorance of facts. In the past, we made the mistake not to explain clearly enough the rather complex chemical reactions that are not as transparent as the production process in other industries."

The second point for CEFIC's priority list will be, Metz adds, what this year has become the all-consuming topic in European business and political life: the "Single Europe Act," scheduled to go into force by 1992. The act will bring about uniformity and harmonization across a broad spectrum of physical, fiscal, and technical issues. It will also build a huge market of 320 million people.

"It is not the industry that is responsible for still-existing barriers," Metz says. "We want them to be removed. The concept of a Europeanwide integrated market fits very well with the philosophy of the chemical industry, which has always supported free trade with as little interference as possible. We should help create awareness and enthusiasm for this great move, so that the momentum becomes so strong that individual hurdles can no longer bring the process to a halt."

On the other hand, with the emergence of a single European market, warned Martin Bangemann, West Germany's minister for economics, there could be an attendant emergence of a "fortress Europe" concept. "I believe it would be wrong if the European Community were to grow together, just to protect itself from the outside," he says. "As we are living in a world growing together, we can't forget the rest: We have to become a fair trading partner for everyone. We are interwoven in the world economy."

Metz: Europewide integrated market

One of the major areas of harmonization will be in environmental standards. At a press conference following the meeting, a number of questions dealt with how these standards would be "harmonized" throughout Europe, the concern being that if the standards are not, then countries with more stringent standards will be at a competitive disadvantage to other countries.

However, according to Aarnout A. Loudon, past president of CEFIC and chairman of Akzo, of the Netherlands, "The chemical industry is often accused of wanting harmonization at the lowest levels," and that, he says, is not true. "At CEFIC, we want harmonization. We will accept high measures, but these will then be equal for all countries in the same level of economic development. We cannot ask for the same levels of environmental protection from countries less developed. We must give them time to build up, economically, so they will be able to afford the outlays."

Patricia Layman, London

Study Traces Most SO_2 Emissions To Burning of Moderate-Sulfur Coal

Department of Energy study says that power plant SO_2 emissions could be cut 50% by clean-coal technologies currently under development

Pamela S. Zurer, C&EN Washington

Toronto

Electric utilities burning moderate-sulfur coal—not those that use high-sulfur coal—are the major source of sulfur dioxide emissions implicated in acid rain, a study by the Department of Energy's Pittsburgh Energy Technology Center (PETC) concludes. These emissions could be cut in half without having to change coal sources or boilers if promising coal-cleaning technologies are successfully developed, the study finds.

The results of the acid rain control initiative study were presented by PETC chemist Dennis H. Finseth at a symposium on controlling emissions from coal combustion. The session was part of a three-day symposium on acid rain that included presentations on atmospheric sulfur species and the effects of acid deposition on soil, water, and materials, as well as strategies for controlling emissions of acid precursors.

"We need to know where sulfur dioxide is coming from—both the geographical origin and what combustion technology produces it," Finseth says. "Without that information it is hard to consider what kinds of control strategies might work."

Accordingly, the DOE researchers assembled information from several databases to create a profile of sulfur dioxide sources. They put together design information on all U.S. coal-fired electric utility boilers from utilities with a generating capacity of more than 50 MW. All together, 1166 units representing a generating capacity of 299 gigawatts—essentially all U.S. coal-burning plants—were identified.

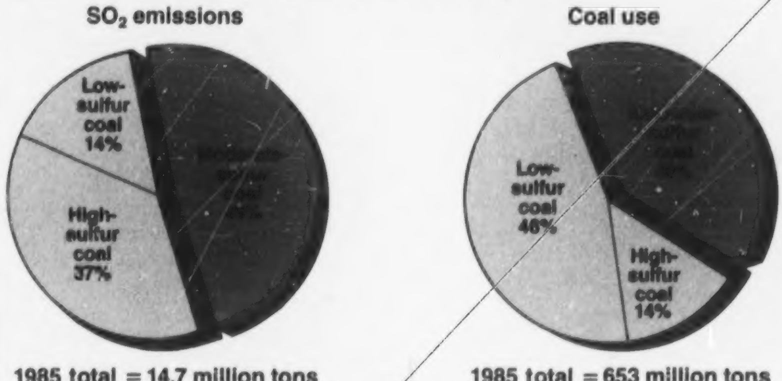
The PETC workers determined the amount, quality, and source of coal used by each boiler in 1985 and estimated the resulting emissions of sulfur dioxide. (The emissions were calculated by assuming that 95% of the sulfur in the coal is converted to sulfur dioxide.) They calculate the sum total of sulfur dioxide emitted in 1985 from electric utilities burning coal was 14.7 million tons, about 100 lb per U.S. resident, as Finseth points out.

The greatest portion of those emissions—7.1 million tons—came from plants burning coal that contains moderate amounts of sulfur—that is, about 0.75 to 2.5% sulfur. That surprising finding is in direct contrast to the generally accepted view that high-sulfur coals are responsible for most sulfur dioxide emissions. The PETC study indicates burning high-sulfur coal produced about 5.4 million tons of sulfur dioxide in 1985.

The researchers also looked at how the age and size of the utility boilers relate to sulfur dioxide emissions. The dominant sulfur dioxide producers, because they burn so much coal, are large plants with capacities greater than 600 MW. Most of these large-scale plants are less than 15 years old.

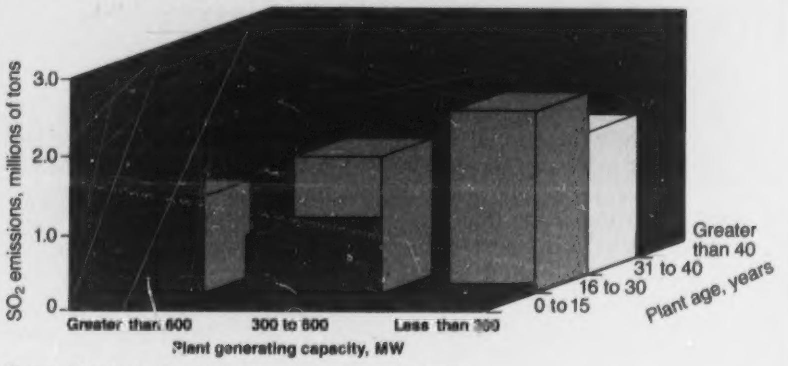
However, a significant portion of sulfur dioxide emissions come from smaller, older boilers that may be near the end of their economic lifetimes, Finseth notes. The diversity in size, age, and design of boilers that emit sulfur dioxide means that a wide range of strategies will be needed to control emissions.

Moderate-sulfur coal accounts for about half of SO_2 emissions, but only 40% of total coal use



Note: High-sulfur coal defined as yielding 4.0 lb or more of sulfur dioxide per million Btu; moderate-sulfur coal, 1.2 to 4.0 lb of sulfur dioxide per million Btu; and low-sulfur coal, 1.2 lb or less of sulfur dioxide per million Btu.
Source: Department of Energy's Pittsburgh Energy Technology Center

Older, smaller electric utility plants emit large amounts of sulfur dioxide



Source: Department of Energy's Pittsburgh Energy Technology Center

With the data on the origins of sulfur dioxide in hand, the DOE researchers examined possible ways to reduce emissions below 1.2 lb of sulfur dioxide per million Btu—a limit older plants may be forced to meet under some proposals for controlling acid rain. They selected two types of moderate-sulfur coal and two high-sulfur coals and investigated the cost and technical feasibility of reducing their sulfur contents by conventional and advanced cleaning methods.

"We tackled the issue by brainstorming," says Richard E. Hucko, acting director of the PETC advanced research division. "Which technologies could play a role and are far enough along in development and economically feasible?"

Advanced cleaning technologies alone could reduce emissions from moderate-sulfur coals to below the limit, the studies find. High-sulfur coals would require some type of flue-gas desulfurization in addition to coal cleaning to meet the standard.

All advanced coal preparation methods are ways of treating coal that has been ground very finely in order to liberate pyrite. (Most sulfur in coal is bound up in the mineral pyrite, iron sulfide.) "Grinding breaks the coal particles apart such that the coal may no longer be physically attached to the pyrite and they can be separated," Hucko says. Based on their technical capabilities and readiness for commercialization by 1992, three technologies were identified by the study as most promising for removing pyrite from coal: selective agglomeration, heavy-liquid cycloning, and advanced froth flotation.

In selective agglomeration, an aqueous suspension of the finely ground coal is mixed vigorously with a liquid that is immiscible in water. The hydrophobic coal particles mass together into large clumps in the organic phase. The mineral particles remain dispersed in the aqueous phase and can be separated from the coal material by screening.

Many of the initial studies of selective agglomeration used either chlorofluorocarbons (CFCs) or *n*-pentane as the organic liquid. The PETC team substituted *n*-heptane in its evaluation of the process, however, because CFCs are set to be regulated under the Montreal Protocol on Substances That Deplete the Ozone Layer and pentane would require explosion-proof process equipment.

Heavy-liquid cycloning takes advantage of the difference in specific gravity between coal and pyrite. A mixture of ground coal and a liquid with a specific gravity between 1.3 and 1.6 is spun in a cyclone. Centrifugal forces move the lighter coal particles toward the center and the heavier pyrite particles to the wall of the cyclone. The clean coal flows out the top and the impurities out the bottom. The PETC study used methylene chloride as the liquid in evaluating the technique.

Advanced froth flotation of coal is an improvement in coal flotation processes already used in commercial coal preparation plants. The study indicates that advanced processes that can separate ultrafine coal particles from pyrite require extremely small bubbles, new cell designs, materials that specifically depress pyrite, or some combination.

Any of the three advanced coal-cleaning technologies could reduce emissions from moderate-sulfur coals below the limit of 1.2 lb of sulfur dioxide per million Btu, Hucko notes. The study indicates the cost would only be about half that of limestone scrubbing of flue gases.

Coal cleaning alone would not remove enough sulfur to bring emissions from high-sulfur coals within the limit. However, advanced coal preparation, combined with treating flue gases by injecting lime into existing utility ducts could adequately reduce emissions, according to the study. The cost of using both methods together would still be less than conventional limestone scrubbing.

As a result of the study's conclusions, PETC has begun a program called the clean coal research initiative to try to advance the technologies identified as most promising. "Our major thrust is to bring the technology to a state of development where private firms could decide if they want to implement it," Hucko says.

Under the program, DOE has solicited and is considering proposals in two main areas. The first group focuses on understanding the surface properties of coal. "Pyrite often mimics coal, which is exactly what we don't want," Hucko says. "We need to try to understand once and for all at a scientific level how to get pyrite out of coal."

The second set of proposals deals with engineering development: how to design equipment and put together systems to implement the processes from grinding the coal on up.

Hucko says DOE expects to award funds for the clean coal research initiative by the end of the fiscal year. "We want to quickly gather data so that private firms can make decisions about using these technologies." □

A1250-1
7/11/88

JULY 4, 1988

CHEMICAL & ENGINEERING NEWS

PRELIMINARY PROGRAM
ACS meeting in Los Angeles
Page 59

0511179C098 9 K AR6627SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Salary Survey

For chemists, earnings higher
and unemployment low
Page 39

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 27
CENEAR 66 (27) 1–92
ISSN 0009-2347

JULY 4, 1988

News of the Week

- **The drought in the Midwest is not expected to hurt the agricultural chemical industry this year and may even result in increased demand next year for fertilizer and pesticide products.** Page 4
- **In an unusual move, *Nature* has published a paper containing research results that the journal's editors and the paper's referees consider unbelievable.** Page 5
- **Congress probes aftermath of the recent explosion of a rocket solid fuel oxidizer plant in Henderson, Nev.** Page 5
- **An environmental conference in Toronto recommends an international convention to prevent global warming by minimizing emissions of "greenhouse gases."** Page 6
- **Bills introduced in the House and Senate would elevate EPA to Cabinet-level status.** Page 6

Cover: Photo by Lew Lause/
Uniphoto Picture Agency

Letters 2
Editor's Page 3

Concentrates
Business 7
Government 15
Science/Technology 21

The Departments
New Products 66
Awards 79
Newscripts 92

Business

Union Carbide's claim that sabotage caused 1984 Bhopal disaster is backed by contract firm it hired to investigate accident; more restructuring and explosion of foreign investment are among changes that lie ahead for the U.S. chemical industry; dramatic decline in U.S. petrochemicals exports by 1990 is forecast by Pace Chemicals consultant. **Page 8**

Government

R&D funding levels are up for most federal agencies in fiscal 1989 appropriations bills passed by House. **Page 16**

Technology

Methane may provide alternative source for ethylene; field uses for ion mobility spectrometry debut; new class of polymer electrodes are versatile and stable; fluorescence of new chelating agent is multiplied 1000 times on complexation; Software/database update, a new C&EN feature to appear on a regular basis, provides information on new chemistry-related programs. **Page 22**

Priestley Medal Address

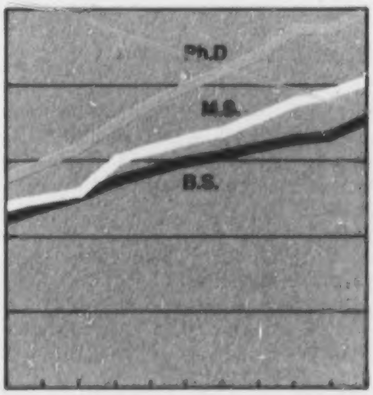
Harvard's Frank H. Westheimer calls for greater emphasis in schools on science and mathematics for nonscientists. **Page 32**

ACS News

Committee on Professional Training reports on 1987 bachelor, master, and Ph.D. graduates of ACS-approved schools; University of California, Berkeley, continues to be top producer of Ph.D. chemists. **Page 49**

Meetings

Preliminary program for ACS national meeting in Los Angeles lists all symposia, includes advance registration form. **Page 59**



Salary Survey

Salaries earned by chemists are up moderately; median salaries this year are 5 to 6% higher than in 1987, the latest ACS survey indicates. Unemployment among chemists, meanwhile, remains at a very low level. Page 39

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036
Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: New York: (212) 697-3223 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 91)

LETTERS

CHEMICAL SAFETY

THF/thionyl chloride explosion

SIR: Recently we experienced an explosion of a 1-gal glass bottle containing approximately a 2:1 mixture of thionyl chloride and tetrahydrofuran (THF). The thionyl chloride had been distilled from a 12-L preparation of an acid chloride. The THF had been added to the distillation to displace the residual thionyl chloride and provide solvent for the succeeding step. Approximately 20 minutes after the THF distillate was poured onto the thionyl chloride, the explosion occurred, completely shattering the bottle.

Extensive thermal studies have been conducted on this system. Results show that an unstirred mixture of THF and thionyl chloride will react violently when heated to about 60 °C, resulting in large temperature and pressure increases. The products of this reaction are bis(4-chlorobutyl) ether, 1,4-dichlorobutane, and SO_2 gas.

We postulate that the explosion was caused by the sudden generation/release of a large volume of SO_2. The energy required to attain the initiation temperature was supplied by a localized change in temperature of about 20 °C when the THF was poured on top of the thionyl chloride. Adiabaticlike conditions in the center of the bottle allowed the solution to slowly self-heat, eventually reaching initiation temperature.

We would like to alert the chemical community to the potential explosivity of certain ratios of THF and thionyl chloride. If such mixtures are to be used, we recommend careful analysis of the hazards.

Randy W. Jackson
Jim Segretario
Mary Cooke
Tim Bryant
Medical Products Dept.
Jackson Laboratory, Du Pont

Motivated by issues

SIR: From time to time I ponder writing, but lack sufficient motivation to respond to issues raised in C&EN. The May 16 issue, however, had three letters that stirred me, and that is too many to let pass.

First, about the "alternative doctorate." Except for a postdoctoral stint at Oak Ridge National Laboratory, all of my post-Ph.D. career has been spent in academia. Both of my appointments have been at small schools that grant only the B.S. and M.S. degrees to chemistry majors. We consistently tout what I thought was the party line in order to encourage our students to go on for the Ph.D.: that even with a master's degree in chemistry, employment will be limited to positions only moderately more elevated than those accessible to persons without degrees. We have had personnel directors say this to our students as well. The message is that if they aspire to move up (to group leaders and higher, for instance) and be able to initiate real, original research rather than primarily carry out assigned tasks, the Ph.D. is a virtual necessity. So, my question to David Schyrer is: Do we in academia need to revise our information? Do you estimate that there is a sufficiently significant percentage of non-Ph.D. chemists doing original research to justify the formal recognition you propose? I am not debating the concept of the proposal. Rather, as a chemist educator, I would like to have my story straight regarding what B.S. and M.S. graduates can expect to find in industry.

Second, in response to Mary Keith's letter on loss of ozone: She angrily castigates tennis players who indulge in "the luxury of the rich" and selfishly promote loss of ozone and its accompanying health and environmental problems. I am a college chemistry professor who plays tennis. Even after being awarded the University Research Award I was entitled to only the same paltry 2.4% salary increase as everyone else here. I am not rich, and I am not getting rich. I might, however, be nearsighted. Let me refer Ms. Keith to another letter appearing in the same issue of C&EN on a similar topic. L. Rinehart writes: "I fully agree that the public should be educated to its own responsibility for the environmental effects of technologies it patronizes, but this does not lift the burden from the people who are creating the chemical hazards, and are making money doing so." I will now write to representatives of the U.S. Lawn Tennis Association to express my opposition to the chlorofluorocarbon-containing tennis balls. What will Keith do? Stop living? Why such a sadly narrow view of life?

Finally, to Lorraine D. Rodriques who wrote that when "a predominately male organization pays me the respect of appointing me," she will accept being called a chairman. Yes, Lorraine, the "women's concerns," of which title is only one very small one, is "an old . . . somewhat boring issue." Yes, Lorraine, "There are better things to do with my time" also. But it is dispositions like yours that perpetuate the concerns!

Continued on page 90

1989 R&D Appropriations Higher for Most Federal Agencies

Many units fare well in budget bills, although cuts are planned in defense research, agricultural R&D, and a number of specific line items

Janice R. Long, C&EN Washington

Moving swiftly compared with previous years, the House has passed all of the fiscal 1989 appropriations bills. These bills are the vehicles used to tell federal departments and agencies just how much money they actually have to spend in any given fiscal year.

As set by the House, total federal R&D spending in fiscal 1989 will be down slightly from current levels, primarily because of a 9%, $3.6 billion, cut in defense R&D spending. Funding for the Strategic Defense Initiative will be held to $3.2 billion, $1.3 billion less than the Administration asked for and $400 million less than is currently being spent on the program.

The House version of the Department of Defense Appropriations Bill, H.R. 4781, also provides $35 million for high-temperature superconductivity research; $100 million for SEMATECH, a joint semiconductor manufacturers' research project; and $95 million for DOD's University Research Initiative. That's an increase of $10 million over current funding levels.

However, DOD won't be able to spend the university money, at least for a while. The bill states that "the Secretary of Defense shall award the funds made available under this act for the University Research Initiative Program on the basis of competition," and that "none of the funds may be obligated or expended until the Appropriations and Armed Services Committees of the House and Senate approve a plan submitted by the Secretary of Defense to provide for broader geographic distribution of funds under such program in comparison to the distribution of such funds during fiscal 1986 and 1987."

Funding for the next largest federal R&D funding agency—the National Institutes of Health—is provided in the Departments of Labor, Health & Human Services, and Education and Related Agencies Appropriation Bill, H.R. 4783. Under the provisions of that House-approved spending plan, NIH gets a budget increase of 8%, or $510 million, to $6.9 billion.

Funding for NIH's Acquired Immune Deficiency Syndrome research programs is up 26%, or $120 million, to $588 million. Funding for the Institute of General Medical Sciences, which funds the lion's share of NIH's academic chemistry research, is up 9% to $623 million.

The NIH appropriations bill includes $4.1 million for investigator-initiated research projects. That amount represents an increase of 10% over current funding. However, contrary to its custom in previous years, the Appropriations Committee did not tell NIH how many new projects to fund with the money. The committee said it no longer believes that the number of projects is an accurate measure of the volume of research being supported.

The committee also noted that NIH's 1989 budget request assumes a 13% decrease in the number of new research project grants and a 10% decrease in the number of noncompeting projects. The committee says it found this unacceptable and told the NIH director to try to address the problem while still maintaining the total number of projects above the 1988 level in 1989.

The biggest R&D program increase allowed by the House, 28%, is for the National Aeronautics & Space Administration, which gets approximately $4 billion in the Department of Housing & Urban Development-Independent Agencies Appropriations Bill, H.R. 4800. Despite the large increase, NASA's total R&D budget is still $280 million less than the Administration wanted.

The Appropriations Subcommittee on HUD-Independent Agencies was told fairly late in the budget process that because of scorekeeping adjustments agreed to in the 1989 budget resolution, its budget allocation had to be reduced $439 million. So the subcommittee had to go back to the drawing board.

It had originally allocated $902.4 million for the space station. But because of the new budget constraints it decided to defer funding of $450 million of space station funds. Those monies will now become available only if the next President submits a special message to Congress indicating that he intends to proceed with the use of the money and the development of the space station program. If the message is not received by April 15, 1989, the program will be terminated. Meanwhile, NASA will have about $60 million per month to spend on the space station program in the first six and one half months of fiscal 1989.

Funding for the Department of Energy's R&D programs is up 3% to $3.9 billion. However, funding to support research and technical analysis is down 6% to $610 million. Within that category, funding for

House votes to trim federal R&D funding

$ Millions	1989 Appropriation	1989 Request	1988	% change Appropriation vs. request	% change Appropriation vs. 1988
Defense	**$35,644.5**	**$38,157.1**	**$39,263.2**	**−7%**	**−9%**
Tactical programs	12,945.7	13,092.7	12,211.7	−1	6
Strategic programs	6,046.7	6,524.6	7,390.7	−7	−18
Advanced technology development	5,072.3	6,507.3	5,433.7	−22	−7
Intelligence & communications	4,478.6	4,469.8	4,882.2	0	−8
Defensewide mission support	3,825.5	4,285.4	4,051.2	−11	−6
Technology base	3,275.7	3,277.3	3,293.7	0	−1
NIH	**6,862.5**	**6,802.1**	**6,352.3**	**1**	**8**
NASA R&D	**4,186.7**	**4,446.7**	**3,274.2**	**−6**	**28**
Energy	**3,941.4**	**3,725.0**	**3,835.6**	**6**	**3**
Energy supply R&D	**1,761.3**	**1,805.9**	**1,816.3**	**−2**	**−3**
Supporting research & technical analysis	610.5	611.6	648.5	0	−6
Fusion	343.0	360.0	335.0	−5	2
Environment	327.0	359.0	338.2	−9	−3
Nuclear	323.2	351.9	347.0	−8	−7
Renewable resources	157.6	123.2	147.6	28	7
Weapons R&D	**969.4**	**964.4**	**959.5**	**1**	**1**
General science and research	**737.9**	**706.9**	**635.4**	**4**	**16**
Fossil energy R&D	**357.4**	**167.0**	**327.0**	**114**	**9**
Conservation R&D	**115.4**	**80.8**	**97.4**	**43**	**18**
NSF	**1,885.0**	**2,050.0**	**1,717.0**	**−8**	**10**
Research & related activities	1,578.0	1,603.0	1,453.0	−2	9
Science education	171.0	156.0	139.2	10	23
Antarctic program	136.0	141.0	124.8	−4	9
Science & technology centers	—	150.0	—	—	—
Commerce	**1,326.7**	**1,222.4**	**1,254.8**	**9**	**1**
NOAA	1,181.9	1,064.4	1,110.0	11	16
NBS	144.8	158.0	144.8	−8	0
Agriculture	**992.8**	**958.8**	**1,037.7**	**4**	**−4**
Agricultural Research Service	568.6	572.0	598.5	−1	−5
Cooperative State Research Service	284.3	257.5	303.7	10	−6
Forest Research	139.9	129.3	135.5	8	3
EPA R&D	**367.2**	**374.8**	**352.2**	**−2**	**4**
TOTAL	**$55,211.8**	**$57,736.9**	**$57,087.0**	**−4**	**−3**

Note: All numbers are estimates. Source: Congressional documents

chemical sciences operating expenses is up 3% to $135 million, but funding for materials sciences is up a bare 1% to $174 million. Funding for DOE's university research support programs is up 40% to $425.8 million. However, funding for university research instrumentation is held constant at $6 million.

The House provided only $100 million of the $363 million that the Administration had requested for the Superconducting Super Collider in the belief that construction should not be initiated until the new Administration has had an opportunity to evaluate the project.

The budget constraints on the HUD subcommittee took their toll on the National Science Foundation's budget, which is also funded under H.R. 4800. The bill provides $1.6 billion for NSF's research and related activities, an increase of 9% over current funding levels, and $171 million for science education, an increase of 23%. That's not too bad, especially when it's compared with what NSF was seeking or might have had.

The HUD subcommittee decided not to provide the five-year, $150 million appropriation NSF had requested to fund its new science and technology centers program. It also did not provide money to fund the $85 million academic research facilities renovation program provided for in NSF's fiscal 1989 authorization bill. Both of these actions were later endorsed by the full Appropriations Committee and later the House.

At the Department of Commerce, funding for the National Oceanic & Atmospheric Administration is up 16% to $1.2 billion, whereas funding for the National Bureau of Standards, as provided by the Appropriations Committee, would be essentially frozen at the fiscal 1988 level of $145 million. NBS money wasn't actually in the Departments of Commerce, Justice, and State, the Judiciary, and Related Agencies Appropriation Bill, H.R. 4782, because its fiscal 1989 authorization bill hadn't been approved before the appropriations bill was acted on.

The Department of Agriculture has the only civilian R&D program that is being cut. It's down 4% to $993 million, primarily because the building and facilities budget for the Agricultural Research Service, which is set at $58 million this year, was cut to $11 million in fiscal 1989.

Other recommendations in the department's appropriations bill include a big rise in funding for the Cooperative State Research Service, which includes increases in funding for groundwater quality research and for the 1890 land grant colleges. The bill does, however, cut the service's competitive grants program, leaving just $29.4 million, a $12.9 million reduction.

The House action, of course, is just the first step in the appropriations process. The Senate must also act on the bills. But if the appropriations bills already reported for floor action in the Senate are any indication, the final R&D budget for fiscal 1989 will be higher, not lower, than what the House has allowed. □

Chemists' Salaries Rise As Unemployment Stays Low

Median salaries for chemists are up about 5 to 6% this year, in line with the trend during the past decade and slightly ahead of the increase in living costs during the past year

The economic status of U.S. chemists remains basically strong this year, according to the most recent survey, conducted this past spring, of members of the American Chemical Society. Unemployment among chemists remains at a very low level—merely 1.0% of ACS members were unemployed and looking for work as of last March—for the second year running. And the salaries earned by chemists this year are comfortably higher than a year earlier.

The median salaries of chemists (the median is the salary that is exceeded by 50% of the respondents to the ACS survey), as of March 1, are 5 to 6% above those earned a year earlier, the survey indicates. This increase is a considerable improvement from that indicated by the similar survey done last year, when median salaries for chemists whose highest degree is a B.S. or M.S. were up only slightly and the median for chemists with a Ph.D. showed no change at all. This year's rise in salaries is about in line with the annual increase in median salaries during the past decade or so.

With inflation having been relatively contained during the past year—the Department of Labor's consumer price index rose only about 4% between March 1987 and March 1988—chemists have moderately improved their income relative to living costs, after having lost ground a bit last year. After adjustment for the cost of living, in fact, salaries have largely made up last

Few ACS members, whatever their status or degree, are involuntarily without a job

	Chemists									
		By sex		By highest degree			By minority status		Chemical engineers	All members[c]
Employment status[a]	Total	Men	Women	B.S.	M.S.	Ph.D.	Minority[b]	Nonminority		
Employed full time	94.3%	95.2%	91.0%	95.4%	95.6%	93.5%	91.8%	94.5%	94.7%	94.3%
Employed part time	1.6	1.1	3.6	1.5	2.2	1.4	1.3	1.6	1.7	1.6
Postdoctoral or fellowship	2.0	1.8	2.5	0.2	0.1	3.2	5.0	1.7	0.6	1.8
Unemployed										
Seeking employment	1.0	0.9	1.4	1.1	0.9	1.0	1.2	1.0	1.3	1.1
Not seeking employment	1.1	1.0	1.6	1.9	1.1	0.8	0.6	1.2	1.7	1.2

a As of March 1, 1988. b Black, Hispanic, American Indian, Alaskan native, Asian, Pacific Islander, or other. c Includes ACS members whose highest degree and present work are in neither chemistry nor chemical engineering. **Source:** ACS survey

Chemists' salaries rose in past year at about the same rate as for the past decade

												Annual change	
$ Thousands	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1987–88	1983–88	1978–88
CHEMISTS' MEDIAN SALARIES[a]														
B.S.	$35.4	$33.5	$33.0	$32.0	$30.9	$30.0	$28.5	$27.5	$25.0	$23.5	$22.0	6%	3%	5%
M.S.	41.0	39.0	37.9	36.0	34.0	33.0	31.6	30.0	26.0	25.0	24.0	5	4	6
Ph.D.	50.0	47.7	47.8	44.0	42.0	40.0	37.5	35.0	31.2	29.0	27.4	5	5	6
All chemists	45.0	42.5	42.5	40.0	38.0	36.0	34.7	32.0	28.9	na	na	6	5	na

a Base annual salary as of March 1, 1988. na = not available. **Source:** ACS survey

Growth in salaries tends to slow for chemists as they become more experienced

Years since B.S. degree	Median salary ($ thousands)ᵃ 0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
NONACADEMIC CHEMISTS											
B.S.											
90%	$29.6	$33.0	$40.0	$51.0	$55.7	$60.0	$74.0	$76.1	$ 75.0	$ 83.0	$56.0
75%	26.1	29.8	35.1	44.0	50.0	52.0	57.0	60.0	62.2	66.4	46.6
50%	24.0	26.0	30.5	37.5	41.4	45.3	45.7	50.0	51.5	51.8	36.0
25%	21.5	22.6	26.7	31.0	34.2	39.0	37.0	41.6	43.8	40.0	28.0
10%	18.7	19.4	24.0	26.0	30.0	29.5	30.0	32.9	35.5	32.0	24.0
M.S.											
90%	—	36.0	41.0	50.6	60.0	66.3	70.0	85.4	80.0	100.0	66.1
75%	—	33.1	37.1	44.8	50.0	53.7	61.5	66.4	68.0	70.0	52.8
50%	—	30.0	32.1	39.6	42.0	46.3	50.8	53.6	56.0	58.0	42.0
25%	—	27.2	27.4	34.0	35.5	39.2	43.7	41.8	48.0	51.4	34.3
10%	—	24.5	24.5	29.0	30.4	32.0	35.0	30.0	41.7	45.2	28.0
Ph.D.											
90%	—	—	48.0	58.0	68.6	80.0	88.0	97.0	100.0	107.0	80.0
75%	—	—	45.0	52.0	60.0	68.0	73.0	78.0	80.5	80.0	66.0
50%	—	—	42.0	47.5	52.8	59.0	63.2	65.0	64.0	67.5	54.8
25%	—	—	40.0	43.0	46.0	50.0	54.5	53.0	54.0	54.0	45.0
10%	—	—	36.6	39.6	40.0	42.5	45.0	45.0	44.5	40.0	40.0

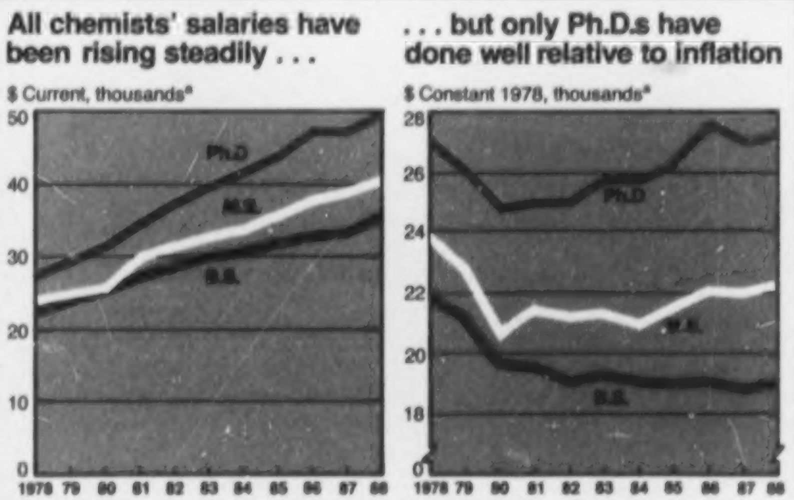
a As of March 1, 1988. **How to read this table:** Using, as an example, nonacademic B.S. chemists two to four years after having received their B.S. degree, 90 of these chemists have annual base salaries of $33,000 or less, 75% have annual base salaries of $29,800 or less, 50% have annual base salaries of $26,000 or less, 25% have annual base salaries of $22,600 or less, and 10% have annual base salaries of $19,400 or less, as of March 1, 1988. **Source:** ACS survey

year's small decline. Even so, the median salary for chemists with no more than a B.S. degree, in constant dollars, remains well below the level a decade ago. For those with an M.S. degree, it is lower, also, although not so markedly. For those with a Ph.D., on the other hand, the median, after adjustment for cost of living increases, is about at the same level as 10 years earlier, after having recovered so far during the 1980s from the steep descent that occurred during the late 1970s.

The median salary for all chemists, of course, is a very broad measure. Even when broken down in terms of highest degree earned, it is a relatively poor indicator of what individual chemists are earning or how their salaries compare with those of their peers and colleagues. More meaningful and useful insights require a look at the data in greater detail. In addition to level of education, for example, salaries tend to be dependent on such factors as length of experience, the type of employer chemists work for, and the type of work they do. That is why the accompanying tables are so detailed.

One bit of information that shows up in such a more focused look is that, as in the past, women chemists continue in general to lag behind their male compatriots in earnings. Because the average age and length of experience of women chemists, as a group, is lower than that for men, the median salary for women would be expected to be lower. But even when a statistical adjustment is made in women's salaries to compensate for this difference, men chemists still have a distinct earnings advantage. (To make this adjustment for differences in experience, the mean salary for men and women must be used for comparison, rather than the median salary.)

The gap—with the average salary for women typically running between 80 and 90% that for men—does not seem to have narrowed appreciably in recent years, moreover. Thus, this year the adjusted mean salary for women chemists with a Ph.D. who are working in industry is 88% that of the mean salary for Ph.D. men with an industrial job; five years ago, the adjust-


All chemists' salaries have been rising steadily . . .

. . . but only Ph.D.s have done well relative to inflation

a Median base annual salary for chemists employed full time as of March 1 of each year. Source: ACS survey

Oil refiners and chemical producers pay highest salaries

Industry	% of industrial chemists: All chemists	B.S.	M.S.	Ph.D.	Mean salary ($ thousands)[a]: B.S.	M.S.	Ph.D.
Pharmaceuticals[b]	16%	15%	19%	16%	$37.0	$44.9	$62.8
Specialty chemicals	15	15	13	15	39.5	45.9	58.8
Basic chemicals	7	4	5	9	43.7	48.9	62.8
Plastics	5	4	6	6	40.7	45.0	62.1
Petroleum and natural gas	4	4	3	4	42.2	50.8	64.5
Coatings	4	6	5	2	38.2	46.0	51.5
Electronics	4	3	3	4	41.0	47.6	62.5
Food	4	4	4	3	40.3	47.4	59.7
Agricultural chemicals	4	3	3	5	39.9	44.1	61.8
Metals and minerals	2	2	2	1	36.0	39.4	53.2
Rubber	2	2	1	1	40.8	40.9	56.6
Soaps and detergents	1	1	1	2	40.3	44.7	61.1
Paper	1	1	2	1	38.0	41.3	56.7
Other manufacturing	18	19	18	18	40.0	49.1	58.9
Nonmanufacturing	12	15	13	9	38.2	46.5	57.1

a As of March 1, 1988; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products. Source: ACS survey

ed mean for women was 86% that for men—no appreciable difference. Similarly, for Ph.D. chemists in the academic world, the adjusted mean for women this year is 82% that for men, little changed from the 84% of five years ago. A bit of a shift toward greater equality between salaries for men and women seems evident, however, in the case of chemists whose highest degree is a B.S. The adjusted mean for such women is 92% of the mean for men for chemists employed in industry and 95% of that for men for those with government jobs. Previous surveys had never shown the mean for women's salaries closer than 88% to that for men in industry or 91% in government in the case of B.S. chemists.

Typically, though, the difference between salaries earned by women and those for men is smallest for younger and less experienced chemists—those who have been awarded their B.S. degree less than 10 years ago. In fact, for industrial chemists the median salary of women with a graduate degree and who earned their bachelor's degree five to nine years ago actually is slightly higher than that for their male counterparts, the ACS survey indicates.

However, among more experienced chemists in industry, men have a clear-cut salary advantage. Thus the median salary for men working in industry with a B.S. earned between 15 and 24 years ago is roughly 20% higher than that for similar women. This pattern is similar to that found in previous ACS salary surveys.

Other factors affecting the size of salaries this year also are similar to those found in earlier surveys. For example, salaries understandably increase with increasing experience.

Attaining rank of full professor improves an academic chemist's earnings markedly

Years since B.S. degree	Median salary ($ thousands)[a]: 5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
PH.D. CHEMISTS EMPLOYED FULL TIME IN ACADEMIA									
Ph.D.-granting schools									
Professor	—	—	$59.2	$56.1	$65.9	$61.0	$64.0	$76.9	$63.4
Associate professor	—	($43.9)	43.9	44.8	48.8	(46.8)	(41.5)	—	44.6
Assistant professor	$35.5	37.9	(37.4)	—	—	—	—	—	37.0
All ranks[b]	31.1	36.9	43.4	50.0	56.8	58.0	62.2	75.0	50.8
Non-Ph.D.-granting schools									
Professor	—	—	(39.0)	46.8	51.2	52.5	55.0	54.4	51.2
Associate professor	—	(35.9)	37.8	40.6	42.7	43.4	(51.0)	(49.6)	41.1
Assistant professor	29.5	33.8	32.9	29.3	—	—	—	—	32.7
All ranks[b]	29.3	33.5	35.4	42.9	48.3	50.9	54.9	52.6	44.0

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. a Base annual salary as of March 1, 1988, excluding summer teaching and other supplemental earnings; salaries of the approximately 60% of academic chemists who have nine- or 10-month contracts are adjusted to a 12-month basis. b Includes instructors, lecturers, research associates, and others not listed separately. **Source:** ACS survey

Women's salaries most closely match those for men among B.S. chemists

Mean salary, $ thousands[a]	B.S.: All chemists	Men	Women	Women as % of men	M.S.: All chemists	Men	Women	Women as % of men	Ph.D.: All chemists	Men	Women	Women as % of men
EMPLOYER												
Private industry	$39.9	$42.6	$39.0	92%	$45.9	$48.0	$39.7	83%	$58.9	$59.9	$52.6	88%
Academic	25.2	27.3	27.1	99	33.2	34.6	30.7	89	43.6	44.7	36.9	82
Government	35.6	36.1	34.3	95	41.2	41.8	35.4	85	51.4	52.3	44.9	86
Other	37.1	39.5	30.2	77	54.3	58.5	39.6	68	57.8	59.4	49.7	84

a As of March 1, 1988; to facilitate comparison, women's salaries are adjusted for the difference in average length of experience between them and men. **Source:** ACS survey

For industrial chemists, salaries are highest for work in management

Years since B.S. degree		Median salary ($ thousands)[a]										
		0 to 1	2 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25 to 29	30 to 34	35 to 39	40 or more	Overall
CHEMISTS EMPLOYED FULL TIME IN INDUSTRY												
Sex												
Men	B.S.	$24.5	$27.0	$32.0	$39.2	$43.0	$48.0	$48.0	$51.0	$54.8	$52.5	$39.9
	M.S.	—	(31.6)	32.1	40.0	42.9	48.9	53.0	60.0	58.0	58.0	45.0
	Ph.D.	—	—	42.0	48.0	53.0	60.0	65.4	68.0	70.0	68.0	56.0
Women	B.S.	24.0	26.0	29.8	35.0	35.0	40.8	49.7	(42.5)	—	—	30.0
	M.S.	—	(29.0)	33.0	37.0	39.5	44.5	(45.0)	—	—	—	36.0
	Ph.D.	—	—	42.5	46.0	51.0	(48.8)	(57.5)	—	—	—	45.5
Work function												
General management	B.S.	—	(32.0)	37.4	40.0	50.0	(55.0)	(49.8)	(53.0)	65.4	(71.6)	45.4
	M.S.	—	—	(30.5)	(46.5)	57.0	(52.8)	(70.0)	(60.5)	(67.2)	(70.0)	56.5
	Ph.D.	—	—	—	(56.8)	60.0	61.7	70.0	90.0	(77.5)	(82.1)	68.7
R&D management	B.S.	—	—	(38.5)	45.6	(50.8)	(50.5)	(67.5)	(60.1)	63.3	(54.0)	51.9
	M.S.	—	—	(38.0)	(45.0)	(46.0)	60.0	65.4	(67.2)	(61.5)	—	57.0
	Ph.D.	—	—	(43.3)	54.0	59.0	69.0	75.0	78.8	81.0	80.0	67.9
Basic research	B.S.	—	27.6	29.5	(33.0)	—	(46.0)	—	—	—	—	30.0
	M.S.	—	—	28.7	36.4	(38.1)	(44.0)	—	(55.5)	—	—	36.8
	Ph.D.	—	—	42.8	48.0	49.8	58.0	59.0	68.0	—	(68.6)	50.7
Applied research[b]	B.S.	25.0	27.1	30.5	39.1	44.0	43.8	42.3	51.0	46.9	(49.8)	35.4
	M.S.	—	(30.8)	33.0	39.6	41.0	49.0	49.5	59.0	53.5	—	40.8
	Ph.D.	—	—	42.0	47.0	51.7	55.3	63.6	61.0	62.0	65.0	50.2
Production[c]	B.S.	(21.1)	26.0	30.8	34.0	40.9	45.3	45.0	(44.7)	(39.0)	—	33.0
	M.S.	—	—	27.8	36.8	36.0	42.9	(41.6)	(52.6)	—	—	36.0
	Ph.D.	—	—	—	(43.0)	(50.3)	(52.8)	(62.0)	—	—	—	51.7
Marketing[d]	B.S.	—	(30.0)	31.9	45.8	(48.0)	(50.0)	57.5	(55.5)	(50.1)	—	42.0
	M.S.	—	—	(35.4)	40.0	53.3	(45.0)	(52.5)	(52.0)	(52.5)	—	47.6
	Ph.D.	—	—	—	(47.0)	(55.0)	58.0	(64.0)	—	(58.1)	—	57.5
Work specialty												
Agricultural and food chemistry	B.S.	—	—	(26.3)	(36.6)	—	—	—	—	(53.8)	—	40.6
	M.S.	—	—	(35.0)	(38.8)	(41.0)	—	(51.9)	—	—	—	37.5
	Ph.D.	—	—	(42.0)	42.4	51.0	58.2	65.7	(61.0)	(89.0)	—	52.1
Analytical chemistry	B.S.	(24.9)	27.0	30.6	35.6	38.6	45.8	44.6	45.4	(39.0)	—	34.0
	M.S.	—	(30.6)	33.2	40.0	39.4	44.4	52.0	(45.0)	(53.0)	—	40.0
	Ph.D.	—	—	42.2	47.5	52.5	59.0	63.0	60.0	60.0	(52.0)	51.6
Biochemistry	B.S.	—	(25.6)	(34.0)	(38.0)	—	—	—	—	—	—	33.2
	M.S.	—	—	(28.0)	(44.0)	—	—	—	—	—	—	42.0
	Ph.D.	—	—	(41.8)	48.0	56.7	56.2	55.0	(73.0)	—	—	53.3
Environmental chemistry	B.S.	(20.9)	24.0	32.0	38.4	39.0	(42.0)	—	—	(55.5)	—	32.3
	M.S.	—	—	(27.8)	(40.0)	(49.4)	—	—	—	(52.5)	—	41.0
	Ph.D.	—	—	—	(53.3)	(54.1)	(55.2)	(52.0)	(65.0)	(80.0)	—	56.0
Inorganic chemistry	B.S.	—	—	(32.0)	(36.5)	—	—	—	(53.6)	—	—	36.2
	M.S.	—	—	—	(43.0)	—	—	—	—	—	—	41.0
	Ph.D.	—	—	(42.0)	48.0	(51.3)	(62.0)	(71.0)	—	—	—	51.6
Materials science	B.S.	—	(22.7)	30.0	39.2	—	—	—	(52.8)	(52.0)	—	41.0
	M.S.	—	—	(35.9)	(41.5)	(55.5)	—	—	—	—	—	45.8
	Ph.D.	—	—	(44.6)	50.0	(53.3)	59.4	70.8	64.3	(62.3)	(59.0)	59.6
Medicinal and pharmaceutical chemistry	B.S.	—	(27.0)	30.0	(33.8)	—	—	—	(50.5)	(63.3)	—	32.5
	M.S.	—	—	32.1	38.0	(41.0)	(46.8)	—	—	—	—	38.5
	Ph.D.	—	—	42.6	47.4	55.0	60.2	73.0	(63.2)	(81.5)	(78.0)	55.0
Organic chemistry	B.S.	—	27.4	30.0	40.4	(46.0)	(43.6)	(45.5)	(54.4)	(56.1)	—	36.5
	M.S.	—	—	—	34.8	(37.9)	(48.0)	—	(55.5)	(59.0)	—	42.0
	Ph.D.	—	—	41.8	47.5	52.5	60.0	65.5	65.0	63.0	(82.0)	54.0
Physical chemistry	B.S.	—	—	—	—	—	—	—	—	—	—	(38.0)
	M.S.	—	—	—	—	—	—	—	—	—	—	48.6
	Ph.D.	—	—	(42.8)	50.0	56.8	57.0	65.0	(76.5)	(66.0)	—	55.1
Polymer chemistry	B.S.	(26.1)	28.0	32.5	42.2	52.5	50.0	50.3	49.0	48.0	(63.4)	42.0
	M.S.	—	—	32.1	40.0	44.0	48.0	(62.2)	(59.6)	58.0	—	47.2
	Ph.D.	—	—	42.0	48.6	53.0	64.1	65.5	69.8	69.3	67.3	55.5

Note: Where no salary data are shown, sample is too small to provide a meaningful figure; data in parentheses are from relatively small samples, as well, and should be viewed with caution. a As of March 1, 1988. b Includes development and design. c Includes quality control. d Includes purchasing, technical service, and economic evaluation. **Source:** ACS survey

Unemployment remains at a low level for chemists this year

Employment status[a]	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978
Employed full time	95.4%	95.4%	94.8%	95.2%	93.7%	93.5%	94.9%	95.6%	95.9%	95.0%	95.7%
Employed part time	1.6	1.5	1.5	1.5	1.7	1.7	1.4	1.1	1.0	2.0	1.0
Postdoctoral or fellowship	2.0	2.0	2.0	1.9	2.9	2.6	2.2	2.2	2.2	1.9	1.9
Unemployed	1.0	1.1	1.7	1.4	1.7	2.2	1.5	1.1	0.9	1.1	1.4

a As of March 1, 1988; excludes chemists who are not employed but not seeking employment. **Source:** ACS survey

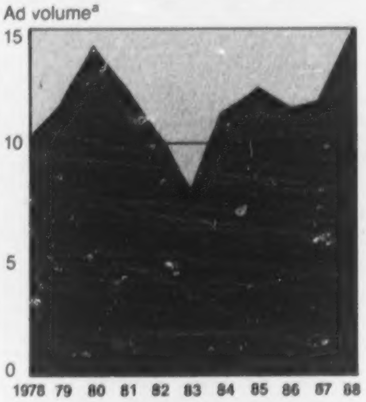
But the median salary of chemists, as they progress through their career, increases much more rapidly early on than in the later stages. The median for B.S. chemists who obtained their degree 20 to 24 years ago and who are not working for a college or university, for instance, is nearly double that for similar chemists who graduated only in the past year. But it rises only 14% further for chemists with 40 or more years of work experience.

This year, as was also typical in the past, chemists working for industrial firms tend to have higher salaries than those employed by government agencies, in academic institutions, or working for other types of employers. And within industry, the highest median salaries are for chemists working for petroleum companies and producers of basic chemicals—although for Ph.D. chemists, at least, companies making pharmaceuticals, electronic equipment, and plastics also rank high. Lowest salaries, on the other hand, are paid by industries in which relatively few chemists find work, such as those producing metals, paper, rubber, and coatings. Salaries are relatively low, also, with companies outside the manufacturing industries.

Among industrial chemists, too, salaries not surprisingly tend to be highest for those working in managerial positions. One reason that women's salaries, even after they are adjusted for differences in length of experience, tend to be lower than those for men is that disproportionately fewer women hold managerial positions.

Among chemists in academia, salaries are clearly higher for those teaching in schools that have Ph.D. programs than in those that don't. Although the ACS survey indicates that salaries paid by colleges and universities are appreciably lower than those earned by chemists who work for other types of employers, it should be noted that the survey results reported here are for the base annual salary from the employee's principal job; they do not include earnings from summer teaching or consulting fees, as well as funds obtained from grants or fellowships.

Volume of help-wanted ads doubled in past five years



a Volume of help-wanted advertising (in thousands of column inches) in C&EN for the 12 months ending with June of each year.

The unemployment rate last March of 1.0% among chemists who are ACS members is about as low as that figure has been since ACS began surveying the employment status of its members in 1971. And although unemployment is somewhat higher for women than men and for chemists who do not have a graduate degree than for those who do, it is essentially at a historically low level for chemists of any type. It is low, too, no matter what type of work an individual has been involved with or where he or she may have been employed. The unemployment rate for chemists is similar to the rate of 1.2% last March for all professional workers in the U.S. labor force.

Joblessness is low for all types of chemists

	% of chemists in category	% unemployed[a]
MOST RECENT EMPLOYER		
Industry	62%	1.0%
Academic	23	0.5
Government	9	1.2
Other	6	2.2
MOST RECENT WORK FUNCTION		
R&D	43%	1.2%
Teaching	13	0.5
R&D management	12	0.8
General management	9	0.8
Marketing[b]	7	1.2
Production[c]	5	0.8
Other	11	1.7
MOST RECENT WORK SPECIALTY		
Analytical	20%	1.0%
Organic	13	0.7
Polymer	12	0.9
Biochemistry	9	0.7
Environmental	8	1.6
Physical	7	1.3
Medicinal[d]	6	0.4
Inorganic	5	1.1
Agricultural and food	4	1.1
Other chemistry	16	1.0

a As of March 1, 1988; excludes chemists who are not employed but not seeking employment. b Includes purchasing, technical service, and economic evaluation. c Includes quality control. d Includes pharmaceutical and clinical chemistry. **Source:** ACS survey

About 3% of the chemists responding to the ACS survey report that they were without work sometime during 1987. This is a slightly lower level of unemployment than indicated by the survey conducted a year earlier (C&EN, Aug. 10, 1987, page 28). As was the case in 1986, women were nearly twice as likely than men to have been unemployed at one time or other last year, and chemists with no more than a B.S. were more frequently jobless than those who have earned a graduate degree.

Most of those who were jobless and seeking work in 1987 were not

Chemists most often learned about their present job through personal contacts

Source of information about current job	Total	By sex Men	Women	By highest degree B.S.	M.S.	Ph.D.	By present employer Industry	Academic	Government	Other
Personal contact or employee referral	45%	45%	43%	41%	42%	48%	41%	54%	54%	43%
Campus recruiting or placement office	13	13	12	11	12	14	17	4	8	7
Newspaper advertisement	12	10	20	22	16	6	14	6	8	9
ACS services	8	9	5	3	6	12	6	18	5	7
Private employment agency	7	7	5	10	8	4	10	a	1	2
Services of other professional organizations	2	2	2	1	2	2	2	3	2	3
Government employment service	2	2	2	3	2	1	1	a	11	0
Other	12	12	12	9	13	13	9	15	11	29

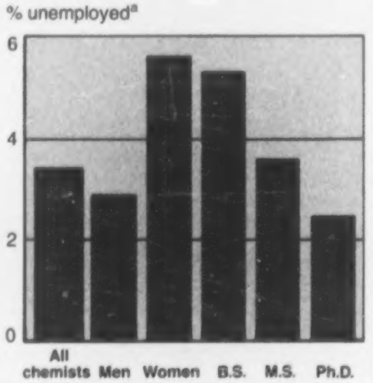
a Less than 0.5%. **Source:** ACS survey

Few chemists were jobless more than six months last year

Months unemployed during 1987	Less than 1	1 to 3	4 to 6	7 to 12
All chemists	15%	44%	25%	16%
Men	18	45	21	16
Women	12	60	23	5
Highest degree				
B.S.	19	54	23	4
M.S.	16	47	17	20
Ph.D.	14	46	22	18

Note: Excludes chemists not in the labor force March 1, 1988. **Source:** ACS survey

About 3% of chemists were jobless sometime in 1987



a Excludes chemists who were not employed but not seeking employment. **Source:** ACS survey

unemployed long: 59% were out of work for only three months or less. Only 16% were without a job for more than six months. Chemists with graduate degrees, however, seem to take more time in finding suitable work. For example, 73% of B.S. chemists but only 60% of Ph.D.s were unemployed for three months or less. On the other hand, 18% of the Ph.D.s were six months or more without work, compared with just 4% among B.S. chemists who were out of work that long.

Strength in the job market for chemists also is apparent in the volume of employment advertising published recently in C&EN, which carries more such advertising aimed at chemists than any other publication in the U.S. Last year, C&EN's volume of classified advertising by employers totaled about 13,000 column inches, up 15% from 1986 and more than for any year since 1980. In fact, 60% more help-wanted advertising ran in C&EN last year than in 1982. And the volume has continued to rise significantly this year. For the 12 months through June, the total has climbed to 15,000 column inches, nearly 30% more than in the 12 months through June 1987. This is strong evidence that demand for chemists is greater now than at any time in the recent past.

For the first time this year, the annual economic survey of ACS members asked respondents, "How did you find out about your current job?" The most frequent source of such information by far is through personal contact or employee referral; 45% of chemists found their job that way. Running far behind as avenues to employment are campus recruiting or college placement offices, the means used by 13% of chemists to find work, and classified advertising in newspapers, which provided jobs to 12%.

ACS services, such as ads placed in C&EN or registration with the ACS employment clearinghouse, served 8%. These ACS services are much more likely to be used by Ph.D. chemists, 12% of whom found employment that way, than by B.S. chemists, only 3% of whom got their job with the help of ACS. Chemists who work in academia also are more likely to get work though ACS services—18% did so—than those who work for other employers. B.S. chemists, on the other hand, are much more likely to obtain jobs through answering newspaper ads than are chemists with a graduate degree. Women, too, are twice as likely as men to find jobs from newspaper ads.

Information on the current salaries and employment status of ACS members is based on nearly 12,000 responses to a mail survey of a random sample of members conducted this past March by the ACS Marketing & Business Analysis Department for the Member & Professional Services Department. The survey was limited to members who have U.S. mailing addresses, are not students, retired, or emeritus members, and who are less than 70 years of age.

More detailed results from this year's ACS survey are available in the report, "Salaries 1988," which can be purchased from the ACS Distribution Office, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. The price of this report is $150. ◻

ACS Committee on Professional Training 1987 Annual Report

The number of bachelor's degree graduates in chemistry from colleges and universities whose undergraduate chemistry programs are approved by the American Chemical Society decreased 5.2% in the 1986–87 academic year from the previous year. The number of master's degrees from these departments rose 1% and the number of Ph.D. degrees continued to rise for the eighth year in a row, this year by 2.6%. These departments project that in 1988 bachelor's degrees will increase 3%, master's will increase 18%, and Ph.D. degrees will increase 14%. (It should be noted, however, that these projections are usually higher than actual counts a year later.)

The percentage of baccalaureate graduates certified to ACS was 41%, slightly less than last year. (Certified graduates are those who have completed the curriculum specified by the Committee on Professional Training (CPT) and are eligible for full membership in ACS; noncertified graduates may become associate members of ACS upon graduation, full members after three years of professional experience or a higher degree in a chemical science.)

A total of 2269 of the bachelor's degree graduates from the approved schools were reported as planning to go to graduate school, and 1874 reported plans to go to professional schools.

Total numbers of bachelor's degrees (certified and noncertified), master's degrees, and Ph.D. degrees awarded in 1986–87 by departments whose chemistry programs are ACS approved are listed by institution in the large table at the end of this report and are summarized in the two smaller tables. These tables also include numbers of chemical engineering graduates from institutions whose programs are accredited by the American Institute of Chemical Engineers and the Accreditation Board for Engineering & Technology. (These departments are not required to report their data to CPT, so the number of departments included varies each year.)

The number of bachelor's degrees in chemical engineering from the 107 AIChE-ABET-accredited departments that reported in 1987 decreased 18% from the total reported by 118 departments in 1986, the fourth decrease in a row. These 107 departments reported an expected further decrease in bachelor's degrees of 10.5% in 1988. At the graduate level, the number of chemical engineering master's degrees decreased for the second year and Ph.D. degrees increased for the eighth year in a row. The number of master's degrees was down 15% from 1986, and the number of Ph.D.s was up 15%. Projected 1988 numbers of master's and Ph.D. degrees in chemical engineering from these schools are up less than 1% for master's degrees and up 32% for Ph.D.s.

The chemistry programs at ACS-approved schools normally are reevaluated at five-year intervals. There were 584 colleges and universities on the approved list at the end of 1987. During the year, the committee studied the chemistry programs of 151 of the approved schools and of 28 schools applying

Summary of totals from 1987 reports from approved schools

	Schools reporting	Men	Women	Total
CHEMISTRY				
Bachelors, Total	582	5581	3257	8838
Certified		2360	1303	3663
Noncertified		3221	1954	5175
Masters	316	1084	552	1636
Doctorates	188	1522	414	1936
CHEMICAL ENGINEERING				
Bachelors, Certified	107	3245	1190	4435
Masters	103	900	178	1078
Doctorates	90	487	46	533

Summary of data from approved schools, 1983–87

	Bachelors				Masters		Doctorates	
	Number of schools	Graduates (total)	Certified graduates	Noncertified graduates	Number of schools	Graduates	Number of schools	Graduates
CHEMISTRY								
1983	570	10,043	4233	5810	320	1569	189	1759
1984	577	9,819	4201	5618	321	1637	189	1777
1985	579	9,679	4021	5658	316	1621	186	1806
1986	580	9,295	3892	5403	315	1620	187	1885
1987	582	8,838	3663	5175	316	1636	188	1936
CHEMICAL ENGINEERING[a]								
1983	122	7,021	7021	—	116	1317	101	333
1984	120	6,866	6866	—	114	1436	101	357
1985	123	6,442	6442	—	118	1489	104	418
1986	118	5,229	5229	—	116	1244	103	460
1987	107	4,435	4435	—	103	1078	90	533

[a] Chemical engineering departments are not required to report their data to CPT, so the number of departments included in this category varies from year to year.

Committee members, 1987

Alice J. Cunningham, *chairman*
Agnes Scott College
Henry A. Bent
North Carolina State University
Norman C. Craig
Oberlin College
Marjorie C. Caserio
University of California, Irvine
Michael P. Doyle
Trinity University
C. David Gutsche
Washington University
Gordon A. Hamilton
Pennsylvania State University
Gordon G. Hammes
Cornell University
Herbert D. Kaesz
University of California, Los Angeles
Karen W. Morse
Utah State University
Shalaby W. Shalaby
Ethicon Inc.
Richard P. Van Duyne
Northwestern University
Barbara A. Gallagher, *committee secretary*
Cathy A. Nelson, *staff associate*
Dolphine S. Hite, *program assistant*
American Chemical Society

for ACS approval. Each evaluation involved a review of extensive documentary materials submitted by the department chairmen describing the current status of the program.

Six schools were added to the ACS-approved list by CPT in 1987; one was put on probation; three were removed from probation; one continued on probation; and two were removed from the list.

With the endorsement of the Board of Directors, CPT proposed programs for optional certifiable chemistry degrees with emphasis in biochemistry, polymer chemistry, or chemistry education. In developing an extension to the 1983 guidelines for approved schools CPT consulted with the American Society of Biochemistry & Molecular Biology, Subcommittee A of the ACS Society Committee on Education, all interested ACS divisions, the ACS-approved schools, and the visiting associates of CPT. By year's end a final draft was being readied for distribution to all constituencies. The committee plans to begin the approval process for optional degree programs during the 1988–89 academic year.

The committee continued its development of a statistical database comprising information collected from five-year re-evaluation reports of ACS-approved schools. However, until the proposed extension of the guidelines is finally defined and suggested modifications in the five-year report form are completed, other nonstatistical sections of the five-year report will not be added to the database.

The ACS Committee on Chemistry & Public Affairs invited CPT to participate in an attempt to develop a long-range science policy, targeting certain areas such as education. CPT has endorsed this approach and offered to provide guidance on any appropriate topics.

Hard copy of the ACS Directory of Graduate Research (DGR) continues to enjoy financial health. However, based on the latest economic factors, CPT voted to cancel the DGR on-line version. CPT is currently investigating the feasibility of converting the DGR concordance database to hard copy for possible inclusion in the directory.

CPT members met with representatives of the ACS marketing staff for a discussion of the educators' perspective of trends affecting the chemical community. The committee also met with a representative from the National Science Foundation's Office of Undergraduate Science, Engineering & Mathematics Education for a discussion of needs in curriculum directions and teaching materials. CPT will forward to NSF a statement of these needs as discerned by the committee.

Other CPT activities in 1987 included continued interaction with the ACS Society Committee on Education Task Force on ACS Involvement in the Two-Year Colleges; discussions with a representative of the Division of Chemical Education regarding the division's study of the content of a two-semester general chemistry course; endorsement of the Association of American Colleges inquiry into the nature and role of the undergraduate major in the arts and sciences; and representation at the National Research Council's colloquium on Calculus for a New Century.

The committee would like to acknowledge and thank the following visiting associates of the committee who conducted on-site visits to schools on the approved list or that are applying for ACS approval during 1987: John P. Chesick, Haverford College; Robert C. Fay, Cornell University; Frank A. Guthrie, Rose-Hulman Institute of Technology; Peter C. Jurs, Pennsylvania State University; William E. McEwen, University of Massachusetts; Brown L. Murr, Johns Hopkins University; William M. Risen Jr., Brown University; Amos B. Smith III, University of Pennsylvania; Wilmer Stratton, Earlham College; and Kenneth Williamson, Mount Holyoke College. □

Graduate student enrollments in departments whose undergraduate chemistry programs are ACS approved

	Number of departments	First-year graduate students		All graduate students	
		Full time	Part time	Full time	Part time
M.S. departments[a]					
Fall 1983	132	452	293	1098	981
Fall 1984	131	468	270	1099	990
Fall 1985[b]	129	417	292	1106	962
Fall 1986	128	474	264	1190	1051
Ph.D. departments					
Fall 1983	189	3554	275	14,037	1380
Fall 1984	186	3404	227	14,194	1314
Fall 1985[b]	187	3455	208	14,379	1372
Fall 1986	187	3475	235	14,438	1355

a Departments whose highest offering is the master's degree in chemistry. b Corrected data from 1986 report.

Chemistry and chemical engineering degrees awarded by ACS-approved schools, 1986–87

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Abilene Christian U	4	9	2	—	—	—	—
Adelphi U	4	1	4	—	—	—	—
Agnes Scott C	1	1	—	—	—	—	—
Akron, U of	27	7	6	8	a	—	—
Alabama, U of							
Birmingham	1	9	4	1	—	—	—
Huntsville	3	4	5	—	a	—	—
University	1	8	2	5	a	—	—
Alaska, U of	1	0	4	—	—	—	—
Albion C	2	10	—	—	—	—	—
Albright C	5	13	—	—	—	—	—
Alfred U	4	0	—	—	—	—	—
Allegheny C	2	13	—	—	—	—	—
Alma C	1	2	—	—	—	—	—
American U	2	1	6	5	—	—	—
Amherst C	0	11	—	—	—	—	—
Andrews U	5	3	—	—	—	—	—
Appalachian State U	4	4	1	—	—	—	—
Arizona State U	22	5	4	8	a	—	—
Arizona, U of	17	28	9	10	22	9	1
Arkansas, U of							
Fayetteville	8	14	2	11	41	15	5
Little Rock	2	3	1	—	—	—	—
Ashland C	1	7	—	—	—	—	—
Auburn U	6	19	4	10	31	6	5
Augsburg C	1	4	—	—	—	—	—
Augustana C							
Illinois	0	11	—	—	—	—	—
South Dakota	2	5	—	—	—	—	—
Austin C	1	4	—	—	—	—	—
Baldwin-Wallace C	2	3	—	—	—	—	—
Ball State U	6	4	5	—	—	—	—
Barnard C	0	24	—	—	—	—	—
Bates C	4	12	—	—	—	—	—
Baylor U	6	12	3	2	—	—	—
Beloit C	3	12	—	—	—	—	—
Bemidji State U	3	10	—	—	—	—	—
Birmingham-Southern C	3	15	—	—	—	—	—
Bloomsburg U	5	4	—	—	—	—	—
Boston C	12	8	6	4	—	—	—
Boston U	2	13	0	7	—	—	—
Bowdoin C	0	40	—	—	—	—	—
Bowling Green State U	5	9	3	—	—	—	—
Bradley U	5	6	0	—	—	—	—
Brandeis U	0	8	2	9	—	—	—
Bridgeport, U of	1	0	7	—	—	—	—
Bridgewater State C	1	7	2	—	—	—	—
Brigham Young U	14	20	6	7	44	6	5
Brown U	0	20	6	17	4	2	0
Bryn Mawr C	20	0	3	3	—	—	—
Bucknell U	4	14	3	—	20	6	—
Butler U	2	9	4	—	—	—	—
California Institute of Tech	16	0	1	30	5	10	17
California Polytechnic State U	15	38	1	—	—	—	—
California State C, Bakersfield	6	1	—	—	—	—	—
California State Polytechnic U	12	6	3	—	a	—	—
Chico	0	11	—	—	—	—	—
Dominguez Hills	2	3	—	—	—	—	—
Fresno	8	7	5	—	—	—	—
Fullerton	7	16	3	—	—	—	—
Hayward	11	6	3	—	—	—	—
Long Beach	13	26	5	—	44	—	—
Los Angeles	12	0	3	—	—	—	—
Northridge	12	16	2	—	—	—	—
Sacramento	18	7	6	—	—	—	—
San Bernardino	0	5	—	—	—	—	—
Stanislaus	2	1	—	—	—	—	—
California, U of							
Berkeley	51	0	13	53	87	8	27
Davis	21	17	1	17	28	3	1
Irvine	14	40	8	12	—	—	—
Los Angeles	25	54	7	22	14	5	2
Riverside	7	1	6	7	—	—	—
San Diego	57	0	22	33	26	6	4
Santa Barbara	16	16	8	9	29	8	4
Santa Cruz	0	21	6	4	—	—	—
Calvin C	2	9	—	—	—	—	—
Canisius C	7	6	—	—	—	—	—
Capital U	1	2	—	—	—	—	—
Carleton C	2	35	—	—	—	—	—
Carnegie Mellon U	13	1	9	4	43	9	4
Carroll C	2	5	—	—	—	—	—
Carthage C	0	4	—	—	—	—	—
Case Western Reserve U	4	31	8	15	39	8	3
Catholic U of America	6	0	2	5	a	—	—
Centenary C of Louisiana	0	3	—	—	—	—	—
Central C	1	9	—	—	—	—	—
Central Connecticut State U	3	1	1	—	—	—	—
Central Florida, U of	15	0	4	—	—	—	—
Central Michigan U	0	16	2	—	—	—	—
Central State U							
Ohio	0	2	—	—	—	—	—
Oklahoma	2	7	—	—	—	—	—
Centre C	0	4	—	—	—	—	—
Charleston, C of	7	10	—	—	—	—	—
Chatham C	6	0	—	—	—	—	—
Chestnut Hill C	1	5	—	—	—	—	—
Chicago, U of	12	24	9	19	—	—	—
Christian Brothers C[b]	—	—	—	—	a	—	—
Cincinnati, U of	21	0	15	12	63	6	5
Citadel, The	1	2	—	—	—	—	—
City U of New York							
Graduate Center	—	—	—	11	—	—	—
City C	2	9	3	—	a	—	—
Brooklyn C	1	29	5	—	—	—	—
Herbert H. Lehman C	3	9	—	—	—	—	—
Hunter C	0	14	0	2	—	—	—
Queens C	2	15	7	—	—	—	—
Clarion U	4	1	—	—	—	—	—
Clark U	10	0	2	8	—	—	—
Clarkson U	7	10	2	2	78	18	5
Clemson U	6	2	9	5	50	9	0
Cleveland State U	23	0	5	2	a	—	—
Coe C	0	7	—	—	—	—	—
Colby C	1	4	—	—	—	—	—
Colgate U	10	4	—	—	—	—	—
Colorado C	7	7	—	—	—	—	—
Colorado School of Mines	4	0	8	8	55	11	3
Colorado State U	11	17	0	18	21	6	1
Colorado, U of							
Boulder	4	42	6	15	45	12	5
Colorado Springs	3	5	—	—	—	—	—
Denver	2	6	4	—	—	—	—
Columbia U	10	6	16	23	22	25	8
Concordia C	0	13	—	—	—	—	—
Connecticut, U of	20	12	3	14	25	10	1
Cooper Union[b]	—	—	—	—	17	—	—
Cornell C	1	5	—	—	—	—	—
Cornell U	20	41	36	27	33	4	12
Creighton U	0	18	2	—	—	—	—
Dartmouth C	0	28	1	6	—	—	—
David Lipscomb C	2	11	—	—	—	—	—
Davidson C	4	2	—	—	—	—	—
Dayton, U of	8	9	—	—	29	6	—
DePaul U	1	7	4	—	—	—	—
DePauw U	3	13	—	—	—	—	—
Delaware State C	2	2	0	—	—	—	—
Delaware, U of	40	25	7	8	41	5	14
Delaware Valley C of Science & Agriculture	5	0	—	—	—	—	—
Delta State U	1	17	—	—	—	—	—
Denison U	3	4	—	—	—	—	—
Denver, U of	4	17	2	0	—	—	—
Detroit, U of	5	7	5	2	a	—	—
Dickinson C	1	8	—	—	—	—	—
Drake U	3	4	—	—	—	—	—
Drew U	2	6	—	—	—	—	—
Drexel U	6	0	13	5	59	11	1
Duke U	9	39	0	15	—	—	—
Duquesne U	1	3	5	0	—	—	—
Earlham C	1	0	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
East Carolina U	8	3	0	—	—	—	—
East Stroudsburg U	4	5	1	—	—	—	—
East Tennessee State U	9	6	2	—	—	—	—
East Texas State U	0	3	1	—	—	—	—
Eastern Illinois U	1	9	8	—	—	—	—
Eastern Kentucky U	5	13	2	—	—	—	—
Eastern Michigan U	11	18	7	—	—	—	—
Eastern New Mexico U	1	4	1	—	—	—	—
Eckerd C	1	1	—	—	—	—	—
Elizabethtown C	3	15	—	—	—	—	—
Elmhurst C	2	13	—	—	—	—	—
Emory U	2	28	2	15	—	—	—
Emporia State U	4	4	2	—	—	—	—
Evansville, U of	4	6	—	—	—	—	—
Fairfield U	3	2	—	—	—	—	—
Fairleigh Dickinson U							
Madison	6	0	0	—	—	—	—
Teaneck	9	7	4	—	—	—	—
Fisk U	7	0	1	—	—	—	—
Florida Atlantic U	6	16	1	—	—	—	—
Florida Institute of Tech	0	1	1	—	17	3	—
Florida International U	5	6	—	—	—	—	—
Florida State U	4	18	6	11	—	—	—
Florida, U of	3	28	2	26	52	5	5
Fordham U	0	13	5	—	—	—	—
Fort Lewis C	4	16	—	—	—	—	—
Franklin & Marshall C	8	12	—	—	—	—	—
Furman U	11	6	1	—	—	—	—
Geneva C	2	7	—	—	—	—	—
George Mason U	5	0	—	—	—	—	—
George Washington U	2	7	0	3	—	—	—
Georgetown U	19	0	6	7	—	—	—
Georgia Institute of Tech	15	0	2	11	91	21	5
Georgia State U	2	5	1	—	—	—	—
Georgia, U of	2	17	3	12	—	—	—
Gettysburg C	4	5	—	—	—	—	—
Glassboro State C	6	0	—	—	—	—	—
Gongaza U	2	1	—	—	—	—	—
Goucher C	1	2	—	—	—	—	—
Grand Valley State C	0	6	—	—	—	—	—
Grinnell C	3	21	—	—	—	—	—
Gustavus Adolphus C	3	11	—	—	—	—	—
Hamilton C	0	3	—	—	—	—	—
Hamline U	4	2	—	—	—	—	—
Hampden-Sydney C	5	2	—	—	—	—	—
Hampton U	2	0	1	—	—	—	—
Hartford, U of	2	0	0	—	—	—	—
Hartwick C	2	0	—	—	—	—	—
Harvard U	0	22	21	13	—	—	—
Harvey Mudd C	12	0	—	—	—	—	—
Haverford C	19	1	—	—	—	—	—
Hawaii, U of	16	3	6	6	—	—	—
Hiram C	4	2	—	—	—	—	—
Hobart & William Smith C	0	4	—	—	—	—	—
Hofstra U	3	5	—	—	—	—	—
Hollins C	0	2	—	—	—	—	—
Holy Cross, C of The	29	5	—	—	—	—	—
Hope C	9	14	—	—	—	—	—
Houston, U	10	1	8	18	35	46	7
Howard U	1	21	3	2	23	3	—
Humboldt State U	0	6	—	—	—	—	—
Idaho State U	6	1	3	—	—	—	—
Idaho, U of	4	8	2	4	17	8	1
Illinois Benedictine C	12	0	—	—	—	—	—
Illinois Institute of Tech	4	0	3	2	30	9	7
Illinois State U	38	0	16	—	—	—	—
Illinois, U of							
Chicago	19	16	17	13	42	22	6
Urbana-Champaign	59	65	11	47	64	18	18
Illinois Wesleyan U	5	2	—	—	—	—	—
Indiana State U	7	0	1	—	—	—	—
Indiana U	23	105	11	26	—	—	—
Indiana U of Pennsylvania	8	9	1	—	—	—	—
Indiana U at South Bend	6	3	—	—	—	—	—
Indiana U Northwest	0	3	—	—	—	—	—
Indiana U-Purdue U							
Fort Wayne	2	6	—	—	—	—	—
Indianapolis	1	24	15	—	—	—	—
Interamerican U of Puerto Rico	0	6	—	—	—	—	—
Iowa State U	16	5	6	34	57	12	11
Iowa, U of	16	0	12	17	21	6	2
Ithaca C	9	0	—	—	—	—	—
Jackson State U	3	4	3	—	—	—	—
James Madison U	5	11	—	—	—	—	—
John Carroll C	3	11	2	—	—	—	—
Johns Hopkins U	15	0	13	12	17	6	1
Juniata C	10	10	—	—	—	—	—
Kalamazoo C	1	14	—	—	—	—	—
Kansas State U	7	11	6	11	13	8	1
Kansas, U of	14	19	3	4	26	5	1
Kean C of New Jersey	9	7	—	—	—	—	—
Kearney State C	0	11	—	—	—	—	—
Kent State U	15	8	0	3	—	—	—
Kentucky, U of	8	14	9	4	26	14	2
Kenyon C	3	12	—	—	—	—	—
King's C	3	3	—	—	—	—	—
Knox C	2	8	—	—	—	—	—
La Salle U	5	3	—	—	—	—	—
Lafayette C	6	6	—	—	21	—	—
Lake Forest C	1	10	—	—	—	—	—
Lamar U	7	1	4	—	23	8	3
Lawrence Institute of Tech	18	0	—	—	—	—	—
Lawrence U[c]	4	2	10	4	—	—	—
Le Moyne C	10	0	—	—	—	—	—
Lebanon Valley C	4	4	—	—	—	—	—
Lehigh U	7	6	11	10	37	19	10
Lewis & Clark C	0	8	—	—	—	—	—
Lincoln U	2	5	—	—	—	—	—
Long Island U							
Brooklyn Campus	3	1	6	—	—	—	—
C. W. Post C	2	0	—	—	—	—	—
Loras C	2	8	—	—	—	—	—
Louisiana State U							
Baton Rouge	7	5	4	14	38	11	3
Shreveport	5	0	—	—	—	—	—
Louisiana Tech U	4	3	3	—	21	4	1
Louisville, U of	5	20	4	4	31	21	1
Lowell, U of	2	1	9	12	27	3	—
Loyola C	1	4	—	—	—	—	—
Loyola Marymount U	3	0	—	—	—	—	—
Loyola U							
Chicago	9	12	4	2	—	—	—
New Orleans	0	5	—	—	—	—	—
Luther C	0	4	—	—	—	—	—
Macalester C	2	8	—	—	—	—	—
Maine, U of, at Orono	3	3	1	2	32	6	2
Manhattan C[d]	4	4	—	—	a	—	—
Manhattanville C	1	1	—	—	—	—	—
Mankato State U	8	17	2	—	—	—	—
Marietta C	1	1	—	—	—	—	—
Marist C	1	0	—	—	—	—	—
Marquette U	13	0	2	1	—	—	—
Marshall U	2	26	3	—	—	—	—
Maryland, U of							
Baltimore County	16	20	1	1	—	—	—
College Park	17	52	10	21	a	—	—
Massachusetts Institute of Tech	39	0	5	37	63	42	21
Massachusetts, U of	15	7	7	21	24	6	10
McNeese State U	3	0	0	—	—	—	—
Memphis State U	6	7	3	0	—	—	—
Mercer U	2	5	—	—	—	—	—
Merrimack C	4	1	—	—	—	—	—
Metropolitan State C	7	19	—	—	—	—	—
Miami U	14	38	5	3	—	—	—
Miami, U of	1	48	3	2	—	—	—
Michigan State U	17	21	7	28	50	3	1
Michigan Tech U	14	0	5	0	56	10	—
Michigan, U of							
Ann Arbor	60	0	22	18	62	10	8
Dearborn	7	6	—	—	—	—	—
Flint	4	6	—	—	—	—	—
Middle Tennessee State U	3	15	2	1	—	—	—
Middlebury C	0	3	0	—	—	—	—
Midwestern State U	4	2	—	—	—	—	—
Millersville U	9	14	—	—	—	—	—
Millsaps C	5	11	—	—	—	—	—
Minnesota, U of							
Duluth	8	6	8	—	—	—	—
Minneapolis	32	0	8	21	92	9	23
Mississippi C	0	8	—	—	—	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
Mississippi State U	5	5	2	1	53	12	0
Mississippi, U of	0	7	1	1	15	5	1
Missouri, U of							
Columbia	10	8	10	4	26	5	3
Kansas City	9	14	2	6	—	—	—
Rolla	13	0	6	5	69	15	7
St. Louis	6	15	11	2	—	—	—
Missouri Western State C	9	0	—	—	—	—	—
Monmouth C							
Illinois	1	2	—	—	—	—	—
New Jersey	3	1	—	—	—	—	—
Montana C of Mineral Science & Technology	2	4	1	—	—	—	—
Montana State U	2	9	4	4	a	—	—
Montana, U of	6	6	3	2	—	—	—
Montclair State C	2	17	3	—	—	—	—
Moorhead State U	4	3	—	—	—	—	—
Moravian C	1	2	—	—	—	—	—
Morehouse C[e]	3	1	—	—	—	—	—
Morgan State U	5	5	—	—	—	—	—
Mount Holyoke C	0	14	1	1	—	—	—
Mount Saint Vincent, C of[d]	0	3	—	—	—	—	—
Muhlenberg C	1	12	—	—	—	—	—
Murray State U	1	13	3	—	—	—	—
Muskingum C	5	6	—	—	—	—	—
Nebraska, U of							
Lincoln	5	14	5	12	23	7	—
Omaha	4	1	—	—	—	—	—
Nebraska Wesleyan U	4	2	—	—	—	—	—
Nevada, U of							
Las Vegas	0	15	0	—	—	—	—
Reno	1	1	1	3	—	—	—
New Hampshire, U of	12	8	8	3	19	6	0
New Jersey Institute of Tech[b]	—	—	—	—	57	17	2
New Mexico Highlands U	0	0	0	—	—	—	—
New Mexico Institute of Mines & Tech	6	0	3	—	—	—	—
New Mexico State U	6	15	2	6	37	2	2
New Mexico, U of	9	2	10	9	14	6	1
New Orleans, U of	2	4	5	5	—	—	—
New York U	3	50	24	12	—	—	—
Niagara U	1	7	—	—	—	—	—
North Alabama, U of	5	8	—	—	—	—	—
North Carolina A&T State U	6	0	6	—	—	—	—
North Carolina Central U	1	7	3	—	—	—	—
North Carolina State U	26	20	8	12	91	5	4
North Carolina, U of							
Asheville	2	1	—	—	—	—	—
Chapel Hill	37	44	15	31	—	—	—
Charlotte	3	9	1	—	—	—	—
Greensboro	6	6	3	—	—	—	—
Wilmington	4	11	—	—	—	—	—
North Dakota State U	1	16	2	7	—	—	—
North Dakota, U of	6	5	1	2	28	7	—
North Texas State U	4	4	6	7	—	—	—
Northeast Louisiana U	4	1	5	—	—	—	—
Northeast Missouri State U	0	10	—	—	—	—	—
Northeastern Illinois U	2	9	2	—	—	—	—
Northeastern U	4	0	6	10	a	—	—
Northern Arizona U	4	19	2	—	—	—	—
Northern Colorado, U of	9	0	3	0	—	—	—
Northern Illinois U	5	14	4	4	—	—	—
Northern Iowa, U of	7	11	0	—	—	—	—
Northern Kentucky U	2	5	—	—	—	—	—
Northern Michigan U	0	5	0	—	—	—	—
Northwest Missouri State U	4	2	—	—	—	—	—
Northwestern State U of Louisiana	0	1	—	—	—	—	—
Northwestern U	6	14	30	28	31	23	9
Notre Dame, U	1	11	8	11	35	6	4
Oakland U	5	6	1	—	—	—	—
Oberlin C	0	13	—	—	—	—	—
Occidental C	3	16	—	—	—	—	—
Ohio Northern U	2	3	—	—	—	—	—
Ohio State U	42	0	17	28	55	11	11
Ohio U	4	11	6	8	8	7	1
Ohio Wesleyan U	1	4	—	—	—	—	—
Oklahoma State U	2	1	8	11	38	15	4
Oklahoma, U of	4	17	7	7	30	10	3
Old Dominion U	8	2	3	—	—	—	—
Oregon State U	7	0	8	12	51	9	2
Oregon, U of	0	25	2	5	—	—	—
Pace U, New York	2	2	—	—	—	—	—
Pacific Lutheran U	2	7	—	—	—	—	—
Pacific, U of The	0	7	0	0	—	—	—
Pennsylvania State U	6	8	10	29	115	12	6
Pennsylvania, U of	6	16	4	25	26	9	12
Philadelphia C of Pharmacy & Science	11	0	2	0	—	—	—
Philadelphia C of Textiles & Sciences	6	0	—	—	—	—	—
Pittsburg State U	3	6	0	—	—	—	—
Pittsburgh, U of	22	48	8	24	72	17	8
Polytechnic U	1	0	10	5	19	6	4
Pomona C	3	4	—	—	—	—	—
Portland State U	7	2	1	1	—	—	—
Pratt Institute[b]	—	—	—	—	a	—	—
Princeton U	22	10	21	21	23	1	8
Providence C	2	3	0	0	—	—	—
Puerto Rico, U of							
Mayaguez	12	8	4	—	43	1	—
Rio Piedras	3	40	7	9	—	—	—
Puget Sound, U of	5	2	—	—	—	—	—
Purdue U	45	15	8	41	122	15	10
Purdue U Calumet	2	1	—	—	—	—	—
Ramapo C of New Jersey	1	8	—	—	—	—	—
Randolph-Macon Woman's C	0	4	—	—	—	—	—
Redlands, U of	0	1	—	—	—	—	—
Reed C	14	7	—	—	—	—	—
Rensselaer Polytechnic Institute	24	0	12	15	47	11	11
Rhode Island C	2	0	—	—	—	—	—
Rhode Island, U of	1	2	4	4	17	7	1
Rhodes C	6	2	—	—	—	—	—
Rice U	4	11	16	13	19	3	17
Richmond, U of	4	9	0	—	—	—	—
Rider C	0	0	—	—	—	—	—
Ripon C	4	2	—	—	—	—	—
Roanoke C	4	2	—	—	—	—	—
Rochester Institute of Tech	7	10	6	—	—	—	—
Rochester, U of	4	7	28	16	27	6	3
Rollins C	1	1	—	—	—	—	—
Roosevelt U	3	1	4	—	—	—	—
Rose-Hulman Institute of Tech	6	0	—	—	41	3	—
Russell Sage C	1	3	—	—	—	—	—
Rutgers U							
Camden C	1	11	—	—	—	—	—
Newark C of Arts & Sciences	11	10	5	4	—	—	—
New Brunswick	23	61	19	16	40	13	4
Saginaw Valley State C	1	10	—	—	—	—	—
St. Anselm C	0	4	—	—	—	—	—
St. Catherine, C of	5	3	—	—	—	—	—
St. Cloud State U	6	18	—	—	—	—	—
St. John Fisher C	6	0	—	—	—	—	—
St. John's U/C of St. Benedict	5	13	—	—	—	—	—
St. John's U	8	0	5	—	—	—	—
St. Joseph C	4	1	6	—	—	—	—
St. Joseph's U	3	15	1	—	—	—	—
St. Lawrence U	1	19	—	—	—	—	—
St. Louis U	5	8	7	—	—	—	—
St. Mary's C	3	7	—	—	—	—	—
St. Michael's C	2	0	—	—	—	—	—
St. Olaf C	6	39	—	—	—	—	—
St. Peter's C	2	0	—	—	—	—	—
St. Thomas, C of	3	4	—	—	—	—	—
Salem State C	3	0	—	—	—	—	—
Sam Houston State U	4	1	2	—	—	—	—
San Diego State U	19	2	10	4	—	—	—
San Francisco State U	4	29	7	—	—	—	—
San Francisco, U of	2	3	3	—	—	—	—
San Jose State U	22	17	6	—	a	—	—
Sangamon State U	3	1	—	—	—	—	—
Santa Clara, U of	2	3	—	—	—	—	—
Scranton, U of	8	13	9	—	—	—	—
Seattle U	3	3	—	—	—	—	—
Seton Hall U	6	9	10	3	—	—	—
Shippensburg U	7	3	1	—	—	—	—
Siena C	6	0	—	—	—	—	—
Simmons C	2	3	—	—	—	—	—
Skidmore C	0	19	—	—	—	—	—
Smith C	3	2	0	0	—	—	—
Sonoma State U	3	8	—	—	—	—	—
South Alabama, U of[b]	—	—	—	—	a	—	—

	CHEMISTRY				CHEMICAL ENGINEERING		
	Bachelor's certified						
	Yes	No	M.S.	Ph.D.	B.S.	M.S.	Ph.D.
South Carolina, U of	2	13	5	24	30	7	2
South Dakota School of Mines & Tech	7	0	2	—	31	2	—
South Dakota State U	2	24	7	—	—	—	—
South Dakota, U of	2	11	2	—	—	—	—
South Florida, U of	10	33	3	5	26	4	1
Southeast Missouri State U	2	7	—	—	—	—	—
Southeastern Louisiana U	4	0	—	—	—	—	—
Southeastern Massachusetts U	4	7	4	—	—	—	—
Southern California, U of	13	2	2	9	27	10	3
Southern Colorado U	3	3	—	—	—	—	—
Southern Illinois U							
Carbondale	10	6	8	3	—	—	—
Edwardsville	8	2	6	—	—	—	—
Southern Methodist U	5	6	0	—	—	—	—
Southern Mississippi, U of	1	16	2	4	—	—	—
Southern Oregon State C	4	2	—	—	—	—	—
Southern U and A&M C	7	0	3	—	—	—	—
Southwest Missouri State U	7	17	—	—	—	—	—
Southwest State U	2	5	—	—	—	—	—
Southwest Texas State U	9	0	0	—	—	—	—
Southwestern Louisiana, U of	0	15	5	—	a	—	—
Southwestern Oklahoma State U	1	4	—	—	—	—	—
Stanford U	5	11	1	25	11	12	7
State U of New York							
Albany	19	7	5	11	—	—	—
Binghamton	12	17	7	7	—	—	—
Buffalo	21	12	6	16	50	6	6
Stony Brook	23	37	2	13	—	—	—
C at Brockport	5	6	—	—	—	—	—
C at Buffalo	7	5	1	—	—	—	—
C at Cortland	1	0	—	—	—	—	—
C at Fredonia	15	4	1	—	—	—	—
C at Genesco	9	1	—	—	—	—	—
C at New Paltz	3	5	1	—	—	—	—
C at Oneonta	2	9	0	—	—	—	—
C at Oswego	10	5	2	—	—	—	—
C at Plattsburgh	6	13	0	—	—	—	—
C at Potsdam	1	15	—	—	—	—	—
Stephen F. Austin State U	6	2	2	—	—	—	—
Stetson U	3	3	—	—	—	—	—
Stevens Institute of Tech	3	4	12	1	12	12	5
Stockton State C	1	13	—	—	—	—	—
Suffolk U	0	2	—	—	—	—	—
Susquehanna U	2	2	—	—	—	—	—
Swarthmore C	4	8	—	—	—	—	—
Syracuse U	13	5	6	6	a	—	—
Temple U	13	6	3	5	—	—	—
Tennessee Tech U	3	6	2	—	a	—	—
Tennessee, U of							
Knoxville	3	13	7	9	55	10	0
Martin	5	9	—	—	—	—	—
Chattanooga	11	16	—	—	—	—	—
Texas A&I U	8	0	2	—	a	—	—
Texas A&M U	10	14	14	24	89	11	7
Texas Christian U	3	14	2	1	—	—	—
Texas Southern U	4	0	7	—	—	—	—
Texas Tech U	13	4	6	10	24	5	1
Texas, U of							
Arlington	8	10	5	1	—	—	—
Austin	66	0	5	27	95	11	19
Dallas	7	0	6	—	—	—	—
El Paso	9	0	6	—	—	—	—
Texas Woman's U	1	5	0	1	—	—	—
Thiel C	0	4	—	—	—	—	—
Thomas More C	1	0	—	—	—	—	—
Toledo, U of	9	9	4	2	23	12	1
Towson State U	0	7	—	—	—	—	—
Trenton State C	11	0	—	—	—	—	—
Trinity C	7	6	0	—	—	—	—
Trinity U	2	4	—	—	—	—	—
Tri-State U[b]	—	—	—	—	15	—	—
Tufts U	0	9	6	2	a	—	—
Tulane U of Louisiana	0	4	1	1	12	5	6
Tulsa, U of	3	0	—	—	13	8	3
Tuskegee U	0	5	2	—	14	—	—
Union C	3	14	—	—	—	—	—
U.S. Air Force Academy	10	3	—	—	—	—	—
U.S. Naval Academy	15	1	—	—	—	—	—
Ursinus C	2	10	—	—	—	—	—
Utah State U	10	0	3	7	—	—	—
Utah, U of	4	23	3	13	a	—	—
Valparaiso U	7	24	—	—	—	—	—
Vanderbilt U	1	12	2	10	21	2	0
Vassar C	0	6	1	—	—	—	—
Vermont, U of	12	0	1	8	—	—	—
Villanova U	4	0	12	8	25	8	—
Virginia Commonwealth U	9	19	2	4	—	—	—
Virginia Military Institute	1	0	—	—	—	—	—
Virginia Polytechnic Institute & State U	17	13	11	13	44	10	6
Virginia, U of	11	90	7	15	18	32	2
Wabash C	5	4	—	—	—	—	—
Wagner C	3	4	—	—	—	—	—
Wake Forest U	0	21	0	1	—	—	—
Washburn U of Topeka	3	3	—	—	—	—	—
Washington C	5	0	—	—	—	—	—
Washington State U	6	6	3	6	34	7	1
Washington U	0	12	11	7	28	13	5
Washington, U of	37	17	10	18	67	16	10
Washington & Jefferson C	1	19	—	—	—	—	—
Washington & Lee U	0	15	—	—	—	—	—
Wayne State U	21	34	7	20	36	5	1
Waynesburg C	2	2	—	—	—	—	—
Weber State C	9	6	—	—	—	—	—
Wellesley C	5	23	—	—	—	—	—
Wesleyan U	4	9	0	5	—	—	—
West Chester U	3	18	6	—	—	—	—
West Florida, U of	5	1	—	—	—	—	—
West Texas State U	0	12	2	—	—	—	—
West Virginia Institute of Tech[b]	—	—	—	—	18	6	—
West Virginia State C	2	5	—	—	—	—	—
West Virginia U	12	45	4	1	35	6	4
Western Illinois U	1	3	8	—	—	—	—
Western Kentucky U	0	14	3	—	—	—	—
Western Maryland C	1	4	—	—	—	—	—
Western Michigan U	3	26	5	1	—	—	—
Western New England C	2	0	—	—	—	—	—
Western Washington U	8	19	0	—	—	—	—
Westminster C	0	4	—	—	—	—	—
Wheaton C							
Illinois	2	7	—	—	—	—	—
Massachusetts	0	7	—	—	—	—	—
Wheeling C	1	8	—	—	—	—	—
Whitman C	3	4	—	—	—	—	—
Whittier C	1	7	—	—	—	—	—
Wichita State U	5	9	4	2	—	—	—
Widener U	1	3	—	—	12	0	—
Wilkes C	2	1	—	—	—	—	—
Willamette U	0	7	—	—	—	—	—
William Paterson C of N.J.	0	4	—	—	—	—	—
William & Mary, C of	22	10	5	—	—	—	—
Williams C	0	23	—	—	—	—	—
Wisconsin, U of							
Eau Claire	6	6	—	—	—	—	—
Green Bay	0	6	—	—	—	—	—
La Crosse	4	8	—	—	—	—	—
Madison	37	6	14	47	97	7	12
Milwaukee	3	18	12	5	—	—	—
Oshkosh	2	5	—	—	—	—	—
Parkside	2	6	—	—	—	—	—
Platteville	0	2	—	—	—	—	—
River Falls	9	7	—	—	—	—	—
Stevens Point	5	19	—	—	—	—	—
Superior	3	6	—	—	—	—	—
Wittenberg U	3	10	—	—	—	—	—
Wooster, C of	2	27	—	—	—	—	—
Worcester Polytechnic Institute	3	4	1	0	28	8	2
Wright State U	12	5	12	—	—	—	—
Wyoming, U of	2	3	3	4	9	6	1
Xavier U of Louisiana	0	49	—	—	—	—	—
Xavier U	2	2	—	—	—	—	—
Yale U	11	0	32	24	3	3	7
Youngstown State U	12	37	0	—	19	0	0
TOTALS	**3663**	**5175**	**1636**	**1936**	**4435**	**1078**	**533**

Note: For brevity, "B.S." and "M.S." are used to denote all bachelor's and master's degrees, respectively, in each column. a Data not submitted. b Listed on basis of accreditation by AIChE-ABET. c Master's and Ph.D. degrees given by the Institute of Paper Chemistry. d The chemistry programs at Mount Saint Vincent and Manhattan College are integrated into a combined department with all instruction in chemistry located at Manhattan College. e Master's and Ph.D. degrees given by Atlanta University.

Berkeley again top Ph.D. producer

For the third year in a row the University of California, Berkeley, has graduated more Ph.D. chemists than any other campus in the U.S. Also for the third year in a row, Indiana University has produced the most chemistry graduates at the bachelor level.

For the past 14 years either Berkeley, six times, or the University of Illinois, Urbana-Champaign, eight times, has been the largest producer of Ph.D. chemists. In the latest year, 1986–87, Urbana-Champaign moves back into the second spot after slipping to seventh the previous year.

At the bachelor's level, Urbana-Champaign was the second largest producer in 1986–87, up from third the previous year, and the University of Virginia moved up into third place from fifth.

These are some of the data that can be gleaned from the latest annual report of ACS's Committee on Professional Training (see page 49). This committee sets standards for chemistry undergraduate programs and monitors them. It also collects data annually on the number of chemistry graduates, at the bachelor's, master's, and doctoral levels, from all departments with bachelor programs it approves.

The latest report indicates that the University of Texas, Austin, moved up from seventh place the year before to become the largest producer of new chemists with undergraduate degrees certified by ACS in 1986–87, replacing Urbana-Champaign, which slipped to third. The University of Michigan, Ann Arbor, took second place, up from third.

Cornell University retained its position as the leading producer of new master's chemists. Yale moved up to second, from fifth. And Northwestern University held on to the third spot.

Purdue was the largest producer of bachelor chemical engineers in 1986–87, with 122. Second was the University of Pennsylvania with 115.

Michael Heylin

These schools had the most chemistry graduates, 1986–87

Total bachelor graduates	
1. Indiana U	128
2. U of Illinois, Urbana-Champaign	124
3. U of Virginia	101
4. Rutgers U, New Brunswick	84
5. U of North Carolina, Chapel Hill	81
6. U of California, Los Angeles	79
7. U of Pittsburgh	70
8. U of Maryland, College Park	69
9. U of Texas, Austin	66
10. U of Delaware	65
11. Cornell U	61
12. U of Michigan, Ann Arbor	60
12. Purdue U	60
12. State U of New York, Stony Brook	60
15. U of California, San Diego	57
15. West Virginia U	57
17. Wayne State U	55
18. U of California, Irvine	54
18. U of Washington	54
20. California Polytechnic State U	53
21. Miami U	52
21. New York U	52
23. U of California, Berkeley	51
24. U of Miami	49
24. Xavier U of Louisiana	49

Certified bachelor graduates	
1. U of Texas, Austin	66
2. U of Michigan, Ann Arbor	60
3. U of Illinois, Urbana-Champaign	59
4. U of California, San Diego	57
5. U of California, Berkeley	51
6. Purdue U	45
7. Ohio State U	42
8. U of Delaware	40
9. Massachusetts Inst of Tech	39
10. Illinois State U	38
11. U of North Carolina, Chapel Hill	37
11. U of Washington	37
11. U of Wisconsin, Madison	37
14. U of Minnesota, Minneapolis	32
15. C of The Holy Cross	29
16. U of Akron	27
17. North Carolina State U	26
18. U of California, Los Angeles	25
19. Rensselaer Polytechnic Institute	24
20. Cleveland State U	23
20. Indiana U	23
20. State U of New York, Stony Brook	23
20. Rutgers U, New Brunswick	23
24. Arizona State U	22
24. U of Pittsburgh	22
24. Princeton U	22
24. San Jose State U	22
24. C of William & Mary	22

Masters graduates	
1. Cornell U	36
2. Yale U	32
3. Northwestern U	30
4. U of Rochester	28
5. New York U	24
6. U of California, San Diego	22
6. U of Michigan, Ann Arbor	22
8. Harvard U	21
8. Princeton U	21
10. Rutgers U, New Brunswick	19
11. U of Illinois, Chicago	17
11. Ohio State U	17
13. Columbia U	16
13. Illinois State U	16
13. Rice U	16
16. U of Cincinnati	15
16. Indiana/Purdue U, Indianapolis	15
18. Texas A&M U	14
18. U of Wisconsin, Madison	14
20. U of California, Berkeley	13
20. Drexel U	13
20. Johns Hopkins U	13
23. U of Iowa	12
23. Rensselaer Polytechnic Institute	12
23. Stevens Institute of Technology	12
23. U of Wisconsin, Milwaukee	12
23. Villanova U	12
23. Wright State U	12

Doctoral graduates	
1. U of California, Berkeley	53
2. U of Illinois, Urbana-Champaign	47
2. U of Wisconsin, Madison	47
4. Purdue U	41
5. Massachusetts Inst of Tech	37
6. Iowa State U	34
7. U of California, San Diego	33
8. U of North Carolina, Chapel Hill	31
9. California Inst of Tech	30
10. Pennsylvania State U	29
11. Michigan State U	28
11. Northwestern U	28
11. Ohio State U	28
14. Cornell U	27
14. U of Texas, Austin	27
16. U of Florida	26
16. Indiana U	26
18. U of Pennsylvania	25
18. Stanford U	25
20. U of Pittsburgh	24
20. U of South Carolina	24
20. Texas A&M U	24
20. Yale U	24
24. Columbia U	23
25. U of California, Los Angeles	22

7/13/88 A1250-1

JULY 11, 1988
CHEMICAL & ENGINEERING
NEWS

Membrane technology expands into many small-scale applications Page 25

International AIDS Conference

Slow progress reported despite intensive research Page 7

0511179C098 9 K AR6628SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 28
CENEAR 66 (28) 1–72
ISSN 0009-2347

JULY 11, 1988

News of the Week

- **A newly released Congressional report contends that U.S. space technology is holding its own when compared with that of the Soviet Union.** Page 4
- **Koppers' chemical unit is being sold to a management group from Koppers and Gordon Cain's Sterling Group; Cain will be chairman of the new company.** Page 5
- **Research in several institutions advances understanding of the role calcium plays in the biochemistry of vision.** Page 5
- **Eligible veterans will begin to receive agent orange settlement payments early next year, following Supreme Court removal of final legal roadblocks.** Page 6
- **Department of Energy report says cost of cleaning up DOE's nuclear test sites to comply with environmental laws will be $45 billion to over $70 billion.** Page 6

Business

U.K. lead alkyls producer Associated Octel is moving to diversify in face of phaseout of use of lead alkyl antiknock compounds in gasoline. **Page 16**

Government

Recommendations for accelerating the usefulness of superconductivity are outgrowth of recent Congressional hearings, Office of Technology Assessment report. **Page 20**

Charges of criminal violations in the handling and disposal of hazardous wastes have been brought against three Department of Defense chemical engineers. **Page 21**

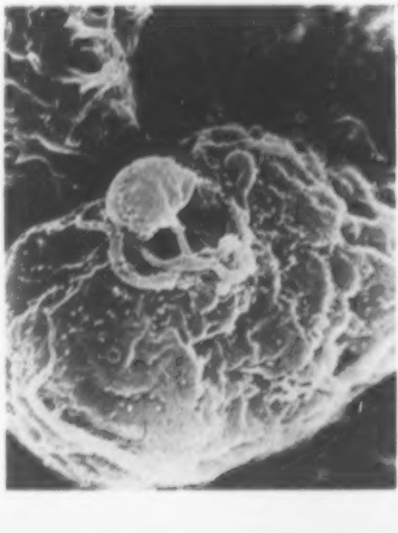
Technology

New membrane technologies are having a growing impact on small-scale processing in the biotechnology, chemical, and petrochemical industries. **Page 25**

Books

"The Toxic Cloud" by Michael H. Brown, a harrowing account of our nation's air quality, sounds a shrill alarm for action. **Page 33**

Letters 2
Editor's Page 3
Concentrates
Business 15
Government 19
Science/Technology 22
The Departments
Meetings 35
Awards 52
Newscripts 72



News Focus

Much has been learned about AIDS in a very short time, but scientists at the 4th International Conference on AIDS, held last month in Stockholm, state clearly that the most difficult work lies ahead—finding effective therapy for the disease or developing a vaccine against it. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 71)

LETTERS

Stereotyping hurts

SIR: I would like to thank Erica Harvey for her well-reasoned, well-researched, and timely letter (C&EN, May 30, page 2) concerning C&EN's stereotyping of women as mindless sex objects and self-centered consumers. It is surely time for ACS and its publications to become sufficiently sensitive to the human condition to realize that stereotyping hurts. Blatantly false stereotyping hurts a lot.

Your treatment of women hurts both men and women and helps perpetuate the false picture you present. Some men are mindless sex objects and self-centered consumers. Some women are scientists and social leaders. It is not asking too much of you to ask that you respond to Harvey's letter by doing what you should have done already: Keep C&EN's pages free of the business-as-usual prejudice that is so common in our society that we are not even supposed to notice it.

Edward McC. Roberts
North Tarrytown, N.Y.

Energy efficiency

SIR: Walter Pittman should follow his own advice and undertake a "modicum of research (with an open mind)" (C&EN, May 23, page 2). If he had done so, he would have concluded that energy efficiency, not nuclear power, exacts the least cost in human lives and pocketbooks of all energy services.

Since Congress mandated least-cost utility planning in the four northwestern states in 1980, that region has shelved plans for virtually all of the 16 planned coal and nuclear power plants. Why? The region found an abundance of energy efficiency investments at far below the cost of building power plants. Nationwide, efficiency improvements have displaced the equivalent of 14 million barrels of oil per day since 1973, saving Americans over $130 billion on yearly energy bills. Recent Congressional testimony shows that those impressive savings can be doubled over the next decade or so through the further use of highly efficient lights, motors, and appliances.

The savings worldwide are equally staggering. The newly published "Energy for a Sustainable World" by Goldemberg et al. indicates multitrillion dollar savings by relying on efficiency over the next half century. As a result, coal combustion would decline 20% instead of rising 2 to 3.5 times and nuclear power would level out at 460 gigawatts(e) instead of climbing to between 2200 and 3700 GW(e). In the former case, acid rain and global warming would be somewhat mitigated; in the latter, several million kilograms of weapons-grade plutonium would not be produced.

Claudine Schneider
Member of Congress
2nd District, Rhode Island

Chitin and chitosan

SIR: Joseph Nagyvary's special report, "The Chemistry of a Stradivarius" (C&EN, May 23, page 24), comments on the use of chitin in violin construction.

The commercial production of this polymer has been fostered by the national Sea Grant program and there are now a number of fledgling manufacturers in the U.S. as well as around the world. Exciting new applications are continually being discovered, particularly in the biomedical area. However, development has been slowed because many potential users are ignorant of the existence of this unique polymer and its close relative, chitosan.

Unfortunately, this situation is likely to persist if authors like Nagyvary do not make clear the difference between chitin and chitosan. Both polymers have a poly-β-D-glucosamine backbone, but while chitin is highly acetylated on the amino groups, chitosan is substantially deacetylated. These differing degrees of acetylation make the essentially neutral chitin totally insoluble in boiling water or vinegar. On the other hand, basic chitosan dissolves readily in dilute acetic acid (vinegar) to afford a powerful, film-forming, wood adhesive or varnish.

It therefore seems more likely that chitosan, rather than chitin, was used in the manufacture of violins. The fabled misinformation tradition of luthier Guadagnini and patron Count Cozio di Salabue apparently lives on in Texas.

G. Graham Allan
Professor of Fiber and Polymer Science
University of Washington, Seattle

Inspired by Steele

SIR: I was surprised, pleased, and fascinated to learn that Arnold Beckman was inspired as a 9-year-old by one of Steele's books on chemistry (C&EN, May 9, page 40). I, too, was inspired at an early age by one of Steele's books.

This excerpt appears in a personalized history of the invention of the heart lung machine that my wife, Eleanor, and I wrote a few years ago: "I probably would have done more in woodworking

Continued on page 52

High court lets agent orange settlement stand

With final legal roadblocks removed by the Supreme Court, some Vietnam veterans can look forward to receiving compensation for exposure to agent orange during their tours there.

On June 30, the justices declined to hear objections to a May 1984 settlement between most veterans seeking compensation for agent orange exposure and the seven chemical companies that manufactured the herbicide during the war. This was the last of several challenges to the settlement. Under the original settlement, the companies agreed to a $180 million compensation figure. But compound interest has raised that total to about $240 million.

The plaintiffs wanted to continue their suit against the companies. But the high court let stand a lower court ruling that the companies were immune from further liability in this instance. About 2400 veterans chose not to take part in the original settlement, but they are eligible to receive benefits from the fund.

Judge Jack B. Weinstein of the Federal District Court in Brooklyn, who heard the agent orange case and helped develop the settlement plan, indicated that payment to veterans will begin early next year. Of nearly 250,000 claims on the settlement, about 40,000 to 60,000 veterans may be eligible for payments. Of the funds available, $170 million will provide cash benefits to veterans considered totally disabled and to the families of veterans whose deaths have been linked to agent orange. Average payments are expected to be about $5700, but may be as high as $12,000. Death benefits go up to $3400.

Of the remaining funds, $52 million will be set aside for social service projects to help veterans and their families, and $5 million will go to Australian and New Zealand personnel exposed to agent orange. Attorneys' fees and other costs for the litigation are pegged at $13 million.

Agent orange toxicity is one of today's most prominent scientific controversies. Studies have shown little or no link between exposure and pathology, but research efforts by the Air Force and the National Institute for Occupational Safety & Health are continuing. Manufacturers of the herbicide have repeatedly denied any liability.

Judge Weinstein has chosen Aetna Life Insurance Co. to serve as claims administrator, and veterans can get claims information from a toll-free telephone number, 1-800-645-1355.

David Hanson

High price tag seen for cleanup of nuclear sites

The taxpayers of America are facing a bill for tens of billions of dollars to bring nuclear weapons facilities and test sites into compliance with current environmental laws. If more stringent laws are enacted the cost will be much higher.

In a new report the Department of Energy estimates that at least $40 billion and perhaps more than $70 billion will be needed to control air and water pollution and clean up contaminated soil at its nuclear sites. That's in addition to the $700 million per year DOE is already spending on its environment, safety, and health programs. And the estimates do not include the cost of disposing of the highly radioactive waste byproducts of weapons production or of decontaminating weapons reactors once their useful life is over.

The report was requested over a year ago by Sen. John Glenn (D.-Ohio), chairman of the Senate Governmental Affairs Committee. In releasing the report, Glenn said that "it puts a price tag on the shameful neglect of DOE and its predecessor agencies toward the health and safety of the public." Previous, less exhaustive studies have reckoned a much higher price tag than DOE's estimate.

In the report DOE notes that increasingly stringent requirements are being applied to facilities that were designed and constructed in the 1940s and 1950s when national security was the primary concern and there was little understanding of the scope and impact of then-acceptable industrial operations on the environment. Still, it says many of today's requirements could be met within five to 10 years, and almost all within 20 years, "if adequate funds are made available."

That's a big if. As DOE notes, a large number of requirements are being applied to defense facilities "at a time of considerable budgetary restraint. This poses a major challenge for DOE, the Congress, and the nation."

Janice Long

Cleanup of weapons facilities could cost $70 billion plus

		Post 1995	
$ Millions	1988-95	Expected	High
Savannah River Plant, Aiken, S.C.	$ 3,662	$ 1,149	$ 8,880
Hanford Site, Richland, Wash.	2,435	27,030	46,130
Feed Materials Production Center, Fernald, Ohio	1,198	1,047	1,280
Y-12 Plant, Oak Ridge, Tenn.	1,094	340	680
Los Alamos National Laboratory, Los Alamos, N.M.	1,094	1,017	1,542
Nevada Test Site, Las Vegas, Nev.	634	250	750
Idaho National Engineering Laboratory, Idaho Falls, Idaho	633	515	2,060
Rocky Flats Plant, Golden, Colo.	576	120	190
Pantex Plant, Amarillo, Tex.	505	184	235
Lawrence Livermore National Laboratory, Livermore, Calif.	500	60	300
Kansas City Plant, Kansas City, Mo.	287	7	11
Sandia National Laboratories, Albuquerque, N.M.	232	55	70
Mound Plant, Miamisburg, Ohio	228	58	78
Pinellas Plant, Largo, Fla.	42	9	9
Sandia National Laboratories, Livermore, Calif.	29	1	3
TOTAL	$13,149	$31,842	$62,168

Source: Department of Energy

A1250-1
7/21/88

JULY 18, 1988

CHEMICAL & ENGINEERING

NEWS

0511179C098 9 K AR6629SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIUNS
BETHESDA MD 20814

Is Academic Pork on the Wane? Page 7

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 29
CENEAR 66 (29) 1–60
ISSN 0009-2347

JULY 18, 1988

News of the Week

- **New report on biotechnology by the Office of Technology Assessment pointing to the promises, pitfalls of this industry was focus of Capitol Hill conference.** **Page 4**
- **Pharmaceutical Manufacturers Association has identified 81 biotechnology-based products that are in clinical trials in the U.S., a surprisingly large number.** **Page 5**
- **A number of chemists were among the 30 persons who received the National Medal of Science or the National Medal of Technology at a ceremony in Washington, D.C., last week.** **Page 5**
- **U.S. team placed third at 20th International Chemistry Olympiad held in Helsinki earlier this month.** **Page 6**
- **Amoco will build new carbon fiber plant based on polyacrylonitrile feedstock in response to law requiring DOD to obtain more than half its PAN-based carbon fiber from domestic sources.** **Page 6**

Business

Propylene supply is tightening as demand for the monomer's use in chemicals and polymers continues to grow at a strong rate. **Page 19**

Government

Bill aimed at preventing chemicals from being diverted from legitimate uses to the synthesis of illegal drugs has reached the House floor; attempt to end federal payments for banned pesticides was defeated in close House vote. **Page 22**

Science

Science should be made a central goal of space program, NRC panel urges; electronic bulletin board for organic chemists debuts; spectrum of dimethoxycarbene recorded. **Page 27**

Technology

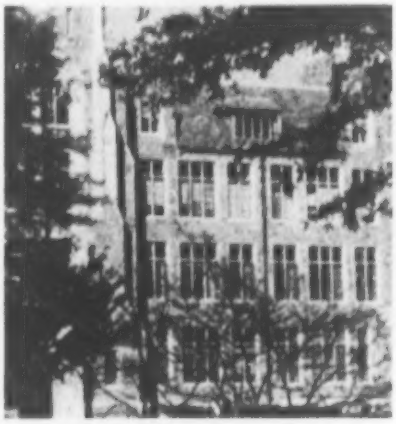
Compressed air dryer based on membrane system is developed; batch synthesis of peptides achieved by new solid-phase process; surface-treated kaolin filler improves qualities of nylon. **Page 35**

Books

"The Breakthrough: The Race for the Superconductor" by Robert M. Hazen recounts author's personal involvement in the superconductor drama. **Page 40**

ACS News

ACS Board approves 160 new or continuing Petroleum Research Fund grants totaling $4,422,994. **Page 43**



News Focus

Debate continues over pork-barrel science versus the peer review system: Which is best for science and the national interest? **Page 7**

Letters 2
Editor's Page 3
Concentrates
Business 17
Government 21
Science/Technology 26
The Departments
ACS Comment 42
Awards 46
Newscripts 60

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 59)

LETTERS

CHEMICAL SAFETY

Barium acetate pyrolysis

SIR: Following a minor explosion while pyrolyzing a mixture of barium acetate and mixed metal oxides, N. Fleischer (C&EN, April 11, page 2) proposed to eliminate the problem by purging the reaction tube, preferably with oxygen.

This would in fact be highly dangerous and would virtually guarantee a violent explosion. Pyrolysis of calcium acetate at 400 °C was used formerly to produce acetone industrially, and pyrolysis of 1 g of barium acetate could produce up to 0.22 g of acetone. As the lower explosive limit is 2.6% by volume in air, this amount could give some 5 to 10 L of explosive mixture at 350 °C.

In oxygen atmosphere both the lower explosive limit and autoignition temperature are greatly reduced, and extreme danger would be likely if oxygen purging were used. There is no substitute for inert gases for this purpose.

I have just learned of a violent explosion in oxygen-flask analysis, where the technician, "to ensure proper ignition," moistened the filter paper round the sample with just one drop (0.05 mL) of acetone before igniting the tail and insertion into the oxygen-filled flask. Fortunately the mesh guard retained the fragments. Human ingenuity for self-destruction knows no bounds!

L. Bretherick
Bridport, Dorset, U.K.

Well-grounded in chemistry

SIR: David E. Henrie recently bemoaned the reliance of chemists on such concepts as atoms and orbitals rather than physical properties observable by the human senses (C&EN, April 25, page 3). I would like to point out that the data we receive from our external spectrometers are just as valid as the data received by our internal instrumentation—eyes, ears, and so on. Furthermore, the innate model of reality that we carry around in our heads is not inherently more accurate than the models proposed by theoretical chemistry. As chemists, we are all too aware of how easy it is to be misled by the results from a single experiment. A brief consideration of optical illusions emphasizes that data from our biological instrumentation can be misleading as well.

It is irrelevant whether or not our descriptions of reality are, in fact, "true," as long as they enable us to accurately predict reality. Towards these ends, the quantum mechanical description of matter is by far the most successful treatment we have devised. A student well-grounded in the theory of chemistry is able to contribute much more to the advancement of the science than a student who has memorized the physical properties of a million or so compounds, most of which he or she will never come in contact with. The concepts of chemistry are the very essence of the science.

Henrie's disdain of theory leads him to conclude that attempting to understand brain activity in terms arising from that activity is akin to grabbing one's own waist and lifting oneself off the ground. If an understanding of the brain could arise only from a complete physical description of the action of each neuron, this might indeed be the case. A well-designed model, however, is like—if I may mutilate an analogy—a block and tackle, enabling us to lift our understanding beyond the mundane.

Clearly theory without observation is futile, but observation without a theoretical framework is useless. Theoretical considerations are very rightly a part of the chemistry curriculum at every level.

Timothy Hanks
Postdoctoral Research Associate
University of Minnesota

Environmental issue

SIR: I see that the Business Roundtable has blasted the "Clean Air Standards Attainment Act of 1987" (C&EN, March 14, page 5). Among other terrible consequences, they say it would eliminate up to 600,000 jobs, and harm U.S. competitiveness in international trade.

When an environmental issue, such as carcinogenicity of vinyl chloride or acid rain, is raised, the response of the chemical industry generally goes through four phases. The first phase is to deny categorically that a problem exists. The second is to say: "Well, there is a slight problem, but it is much less than people say." The next phase is to say: "Yes, there is a problem, but to correct the situation would be prohibitively expensive, will cause layoffs, and will severe-

Continued on page 59

Correction

- June 27, page 3: In Simon Bauer's letter, in the experiments cited, the unimolecular rate constants are pressure independent over the range 5 to 1100 torr, not 1100 to 1105.

Efforts To Stem Pork-Barrel Science Funding Likely To Be Unsuccessful

Use of Congressional spending bills to fund academic science projects at specific sites—thus bypassing the peer review system—is still being criticized by "have" institutions, praised by "have-not" schools

Lois R. Ember, C&EN Washington

If your college or university is part of what some call the academic old-boy network, you are likely to condemn it. If your institution is not, you probably think it's a dandy way to get federal funding for science projects. The "it" is earmarking—the Congressional practice of specifying in spending bills those campuses that are to receive funds for specific projects, thus bypassing traditional peer, now called merit, review.

The cognoscenti call it academic pork or pork-barrel science.

Pork barreling is a well-established prerogative of Congress, a Constitutional right even. Members of Congress have long used it to bring economic prosperity to their states or districts, usually in the form of highways and water projects. Until the early 1980s, academic institutions generally shied away from the practice.

But after many years of neglect, universities and colleges were facing a crisis: a crumbling infrastructure coupled with slim building reserves and few outside funding sources available to pay for renovating old research facilities or for building new ones. Suddenly pork barreling began to look attractive.

With hat in hand, academics began besieging Congress directly. Congressmen, ever mindful of the economic windfall scientific facilities could bring to their constituents, responded positively. A new era was inaugurated: postindustrial pork.

Although there is a story that the phrase pork barrel dates back to plantation days in the Old South, William and Mary Morris in their book "Morris Dictionary of Word and Phrase Origins" (Harper & Row, 1977) offer a more prosaic explanation. According to the Morrises, the more probable, though less colorful, origin of pork barrel is that it is an expression that developed from pork, which had been in common slang use in the sense of graft or patronage since the carpetbagger days of the Reconstruction. As long ago as 1879 the Congressional Record *reports use of the term: "St. Louis is going to have some of this pork indirectly." Later, when legislation such as the Rivers and Harbors Bill became an omnibus vehicle in which patronage plums were distributed by many Congressmen to their constituents, the analogy of packing all the pork into a single barrel became obvious. By 1913 "Fighting Bob" La Follette (Republican Senator from Wisconsin from 1906 to 1925) was writing about "pork-barrel legislation" and the chances are that the expression was in general use even before that time.*

The irony of it all is that as more traditional pork barreling was leveling off or decreasing, academic pork was becoming a growth industry, though always remaining a small percentage of the total federal science budget. Over a four-year period, from 1982 to 1986, earmarked funds skyrocketed from around $2 million to $236 million, says Roy Meyers, communications director for Cassidy & Associates, a Washington, D.C., lobbying and consulting firm that has turned academic pork into an art form.

For several and varied reasons, close observers of the phenomenon believe that the coming fiscal year (1989) may mark the downturn in pork-barrel science. They may be wrong. Though fiscal 1989 budgets are yet to be finalized, a trend is becoming visible: As one budget spigot gets turned off, another gets turned on.

Academic institutions eager to get their share of the pie are increasingly turning to lobbyists who get paid handsome sums to scrutinize federal accounts for bountiful troughs. For the past five years or so, the Department of Energy's budget

Academics turn to Washington, D.C., lobbying firm for a helping hand

The truism, "It's not what you know, but who you know that counts," so aptly fits academic pork barreling—earmarking by Congress of considerable sums of money for specific research projects—that it's easy to forget that this Congressional prerogative has a long and vaunted history.

In the past it has been widely used to bring highways and water projects to home districts. But under an ever-tightening federal budget and a crumbling infrastructure, academic institutions are using this route to get new buildings and equipment.

Generally untutored in the mysterious ways of Washington, an increasing number of universities are turning to lobbyists for help in plotting strategy and in meeting key Congressional players. One lobbying and consulting firm leading academics through the legislative and political maze is Cassidy & Associates. This firm isn't the only game in town, but for its academic clients, it's been a successful one.

It's a reciprocal game, too. Universities have been good to the firm, allowing it to prosper over the past 13 years in the lee of the White House, just a few short blocks from its headquarters.

Cassidy communications director Roy Meyers will not discuss billings, though he does admit that the firm "is doing well." From a small start—three or four people and Tufts University as the only academic client—the firm now boasts a staff of 70 and a list of 80-some clients of which about 42 are colleges, universities, and medical centers.

After successfully getting Tufts president Jean Mayer his long-desired $21.1 million human nutrition research center, Cassidy's client list grew "almost by word of mouth," explains Meyers. Almost but not quite. Cassidy's cachet increased in 1984 after the firm successfully got several millions of dollars earmarked from Energy Department appropriations for two facilities: $5 million for a vitreous-state laboratory at Catholic University and another $5 million set aside for a national center for chemical research at Columbia University.

Even under the Graham-Rudman-Hollings cloud, the firm has been successful in getting facilities for its academic clients. And even as the prime trough—DOE's appropriations—is getting more difficult to tap, four out of six projects earmarked in DOE's fiscal 1989 funding were for universities represented by the firm. Each year its success rate, measured in funding dollars, has grown. "This year is about 10% higher than last year; it's just shifted to differ-

has been the prime target for pork-seeking lobbyists. But as the Energy Department's budget tightens, lobbyists are feasting on more obscure accounts—Treasury, Postal Service & General Government, and the Department of Agriculture's competitive grants program, for example.

Though neither evil nor illegal, pork barreling has precipitated raging debates within academic and government circles. Overlaid with subtle shadings, the issue takes on Byzantine complexities. Just about the only point of agreement is that academic research facilities are in dire straits. Independent and government studies have variously estimated the cost of renovation and new construction at $5 billion to $20 billion over the next decade or so.

Obviously this need will not easily be met. And the pressures that ignited the search for academic pork in the first place are not likely to disappear. Some academic institutions will continue to be urged by their trustees and faculty to seek Congressional favors. Members of Congress will not become immune from constituent pressure for help in revitalizing local economies.

Indeed, pork-barrel science is emblematic of the successful marketing of science and education. The academic community has long argued that economic viability and national competitiveness are the returns on investments in science and education.

Lawmakers considered the argument, not from a broad national competitiveness point of view, but from a more parochial perspective: "What can it do for my local or state economy?" The thriving high-technology economies of Route 128 around Boston and Silicon Valley in California convinced Congress of the argument's merits. And now, "Science is suffering from its own success," says Don I. Phillips, executive director of the National Academies' Government-University-Industry Research Roundtable.

Albert H. Teich, head of the American Association for the Advancement of Science's Office of Public Sector Programs, concurs with Phillips. "Pork barreling is a function of the increasing extent to which the political world views research as being important and desirable," Teich says. Many Congressmen simply want a piece of the action.

The action is there to be had. The federal government has not funded facilities construction in a major way since the 1960s and early 1970s when the government, primarily through the National Science Foundation, ran merit review facilities programs. Then, the thrust "was to expand the capacity to produce new scientists, not to replace outmoded or obsolete facilities," explains a knowledgeable House committee staffer.

Before and since that golden era of facilities funding, the traditional way of getting new buildings at private and public institutions has been through private gifts. Though this still remains the predominant route, building costs have escalated so much that some universities and colleges have turned to Congress for part or full support.

Campuses have never found it easy to get private donations for large-ticket equipment and instrument items. And as the accoutrements of science get more expensive, more academic institutions are going directly to Congress for such funding.

Certainly academic associations such as the Association of American Universities (AAU) don't quibble ent subcommittees," says Gerald S. J. Cassidy, president of the firm.

Knowledgeable about the lay of the land, Cassidy uses the Congressional byways cleverly and well. He served a stint on Capitol Hill as general counsel to former Sen. George S. McGovern's Senate Select Committee on Nutrition & Human Needs (hence the link to nutritionist Jean Mayer, his first client). All of his lobbyists also come with Capitol Hill credentials, having served on key committees or as staffers for key Congressional members. He and his associates operate by cultivating the political kingpins, often with well-timed campaign contributions—to the tune of at least $50,000 annually.

His academic clients pay hefty fees for Cassidy's insider's track in the Congressional old-boy network, sometimes $500,000 yearly. But for those universities reaping the dividends, the fee is small potatoes. Says Boston University president John R. Silber, "Boston University would be far better off if it had used Cassidy & Associates five years earlier."

Cassidy & Associates hasn't done badly by Boston University. The firm helped the institution get federal funding to the tune of $27.5 million for its $125 million Metcalf Center for Science & Engineering.

To date, the firm has lobbied Congress only for money for bricks and mortar and equipment. Gerald Cassidy says his firm will "be sticking to facilities projects. We don't want to become involved in getting federal funding for research."

Cassidy insists that his activities, which he describes as government relations or public affairs representation, "allow institutions to develop a competitive capacity to do research." His firm levels the playing field, so to speak.

As Meyers explains, "We contend that there's an old-boy network whereby the top 20 research schools in the country get the lion's share of federal funding. We help put universities like Tufts and Boston in a position to play with the big boys."

Meyers bristles at the suggestion that pork barreling eventually will undermine the scientific enterprise because it bypasses the traditional peer, or merit, review system that has served it well for years. "It's not a matter of merit. It's a case of competing for some piece of the pie. The issue is money, not the principle, though proponents of peer review argue otherwise," he says.

"Any one of the projects we've been involved in is a viable, good research center. So the proof is in the pudding," Meyers adds.

---

with the need for such funding, only with the method of obtainment. They contend that pork-barrel spending is harmful to science because it compromises merit review, which has been science's dominating principle since the time of Francis Bacon. If continued and expanded, the scientific enterprise could crumple, they argue.

For the most part Congress has confined its earmarking activity to bricks-and-mortar projects and expensive equipment and instrumentation, but the fear is that it will stray into research funding. There is already some incursion there. Earmarks for the Defense Department are largely for research, not facilities.

As Donald N. Langenberg, chancellor of the University of Illinois, Chicago, explains, "The general concern is that if facilities' earmarking is sanctified by practice, there eventually will be no perceived need for science to sanctify research through the merit review process." As the system now operates, adds Teich, "the distribution of funds for research is made within the scientific community. By breaching this, you are opening up the door to political influence not only of awards for facilities but for operating grants."

In a study of the pork-barrel issue for AAU and other associations, Langenberg and colleagues contend that " 'Political' science too easily becomes mediocre science." They offer no support for this assertion, however.

"That's the slippery-slope argument," Cassidy spokesman Meyers charges. "You need to put more faith in Congress. It stills wants research to be peer reviewed," he contends.

Academic institutions that have received earmarked funds rightly say that there hasn't been traditional merit review of facilities since the early 1970s. Further, they insist, Congress is the ultimate arbiter, the ultimate peer so-to-speak. The colorful and feisty president of Boston University, John R. Silber, who leads the charge for institutions seeking Congressional earmarks, argues: "It is merit reviewed in the sense that the only committee of people in the U.S. qualified to assess when and where new facilities ought to be built—namely Congress—has made this review."

The early facilities funds "went to the 'haves,' the top 20 universities who have remained the top 20," Silber says. He contends that the traditional peer review system creates an old-boy network of "have" universities who do their mightiest to ensure that the "have nots" remain so. A source at an institution that advises Congress on science matters says there's been no conspiracy to favor specific research centers with federal funding. "It's the result of 10,000 different decisions. The process is too decentralized for a conspiracy," he claims.

Silber and M. Richard Rose, president of Rochester Institute of Technology, who also has been successful at getting funds from Congress, repeatedly cite a General Accounting Office report they say supports the existence of the old-boy network. The study shows that a large share (42%) of federal research funding goes to a concentrated and fairly stable group (20) of prestigious universities—all members of AAU—located primarily on the East and West Coasts.

AAU's president Robert M. Rosenzweig says, "It has never been the case that federal money is limited to a few universities. There are a few top receiving universities, but the universities change." In fact, GAO shows that there has been some movement within the

Members of Congress differ over the merits of academic pork barreling

Ever since President Reagan took office, his executive branch has been battling with Congress over the issue of pork barreling. As one Office of Management & Budget staffer tells C&EN, "Pork barreling is counterproductive in the extreme."

To end the practice, early this year OMB sent Congress a list of projects it considered "wasteful and unnecessary." Appropriations for these projects totaled $3 billion, a seemingly huge amount, except when compared with nearly $1 trillion in total federal outlays.

OMB got tripped up by its own list. Instead of showing that pork barreling dominates Congressional spending, the list indicates that for the most part pork barreling is on the decline. Except, that is, for academic pork targeted mainly for research facilities and equipment.

Kennedy: richest colleges get richer

Although the practice started slowly and proceeded in a scatter-gun fashion, things changed around 1984. From that time on, members of Congress increasingly earmarked specific projects for specific academic institutions. For various reasons, the spending bills most often used by Congress were those of the departments of Energy and Defense. In fiscal 1988, earmarked funds in DOE's budget totaled about $139 million; DOD's corresponding figure was about $100 million.

Because of budgetary constraints, academic pork barreling appears to have decreased in the fiscal 1989 appropriations for these two departments. What is not clear is whether this marks the beginning of a downward trend—or a one-year aberration.

What is very clear is that Congress does not speak with one voice on academic pork barreling. The fierce debates over the practice usually pivot on the issue of peer review: whether traditional peer review funnels federal research and development dollars to too few academic institutions.

In a recent radio debate, Sen. Edward M. Kennedy (D.-Mass.) said, "The system is biased in favor of elite institutions. . . . The richest colleges get richer, and the poor go fishing." Calling Congressional earmarking a "travesty,"

---

top 20 slots. Only 16 of the 20 have remained the same over a 17-year period. "Glaciers move faster," is Silber's quick retort.

Silber pleads for what he considers a more equitable distribution of resources, which he believes would be the likely outcome of pork-barrel spending. "Pork barreling creates new centers of excellence, new opportunities for scientific excellence," Silber insists. One of which is Silber's school. "Boston University didn't rank in the top 100 20 years ago. Our quality accelerated as we acquired the facilities to attract top scientists," he says.

An Office of Management & Budget staffer dismisses this argument. "Nobody believes that the net result of earmarking is to equalize excellence across the nation," she says.

While Silber argues that facilities attract top-notch people, others argue that puts the cart before the horse, that the game is played by attracting the right people first. "Some people are saying that the key part of research capacity is the people—the minds, the ideas. You want to put the investment in hardware where it will be best used, where the people resources are, where the best minds are," explains Ann Scanley, staff associate with the Research Roundtable.

Who's to say which side is correct? Certainly Silber's school is fortunate to be located in an area with a high concentration of talented people. In other parts of the country, less like Boston, attracting good people to a new facility may be more difficult.

Whether Silber is correct or not, he raises an important issue, one that is really the nub of the bristling debate over peer review science versus pork-barrel science. Which is better for the nation, for its economy and security? A system that seems to perpetuate a small coterie of excellent research institutes, or one that increases the ability of second-tier schools to conduct research and educate future scientists and move into the first rank?

Phillips of the Research Roundtable says, "In the current climate of restrained resources, establishing new centers as opposed to maintaining old ones should be a focused policy decision within the executive branch or Congress, not one based on a lot of disconnected decisions." He argues that "There needs to be a mechanism to review, in some collective way, the facilities' resources of science." Included in this review should be the criteria of geographic distribution and economic benefits. He adds, "The set of procedures and criteria appropriate for facilities should be different from individual investigator projects."

A lot of Phillips' thoughts have been codified in bills that would get the federal government back in the business of funding scientific research laboratories and educational facilities in a more organized way. These bills have been widely supported by the scientific community.

In some quarters that support arises from the belief that a federal facilities program will reduce the pressures on Congress to bring home the pork. According

Sen. Alan K. Simpson (R.-Wyo.) countered, "These [earmarked] projects don't even have to compete on any scientific basis for the funds. Other academically superior efforts simply go without."

Debating on the Senate floor, and picking up on Kennedy's theme, Sen. Dennis DeConcini (D.-Ariz.) said, "One look at the universities that received the research money shows beyond a shadow of doubt that unless your university is on the East or West Coast, you are picking up the crumbs, if anything, of any federal research dollars."

Calling pork barreling a "log-rolling approach," Sen. Jeff Bingaman (D.-N.M.) argued, "It is an issue of a small group of universities which happen to be located in the districts of powerful members of the Congress, . . . a group of universities represented by a high-powered Washington [lobbying firm], Cassidy & Associates, versus all the other institutions in the country . . . who would otherwise have a chance to receive these funds but have not signed up with Washington lobbyists to make their case."

Simpson: superior efforts go without

Though he accepts traditional peer review for research projects, Sen. Mark O. Hatfield (R.-Ore.) contends that "it is a static system that fails to take into account the related economic and social factors relevant to funding decisions for facilities."

Rep. Robert S. Walker (R.-Pa.) thinks otherwise. "A handful of people are making these decisions based on criteria that have absolutely nothing to do with science. . . . If we are to be competitive as a nation, in a world economy, [we have to] assure ourselves that we are first of all getting the very best science that's available to us," Walker says.

Walker doesn't sanction pork barreling but he doesn't lay the entire blame for the phenomenon at the feet of Congress. "It's the universities themselves that are sometimes the cause of [Congressional] interference by sidestepping the established process. They have to maintain more self-discipline than they have shown in the past," he advises.

to Robert L. Park, president of the American Physical Society, "Pork barreling will continue until there is some kind of federal program for facilities construction." His group along with AAU and other academic associations have vigorously lobbied for this program, partly to offset some of the antagonism they engendered on Capitol Hill.

With AAU president Rosenzweig as their chief spokesman, these groups went before one Congressional committee after another arguing that scientific peers, not Congress, should be making the decisions on who should get research funds and where buildings should be built. The more they testified, the more they infuriated Congress, says a close observer of science funding issues. "Congress began to view the Dupont Circle group [university associations located at that address in Washington, D.C.] as having unreconstructed arrogance," says Alvin W. Trivelpiece, now AAAS executive officer but formerly an assistant DOE secretary.

It got so bad that former Sen. Russell B. Long (D.-La.), debating the issue on the Senate floor a couple of years ago, asked: "When did we agree that the peers would cut the melon or decide who gets the money? . . . I do not recall that I ever agreed to that."

A committee staffer says Congress found the associations' attitude a "bit self-serving" in that they appeared to be arguing for the status quo. It would have been better for the academics "to appeal to Congressmen's understanding for the need to sustain a certain minimum level of peer-reviewed funding, and let Congress play games above that level," he contends.

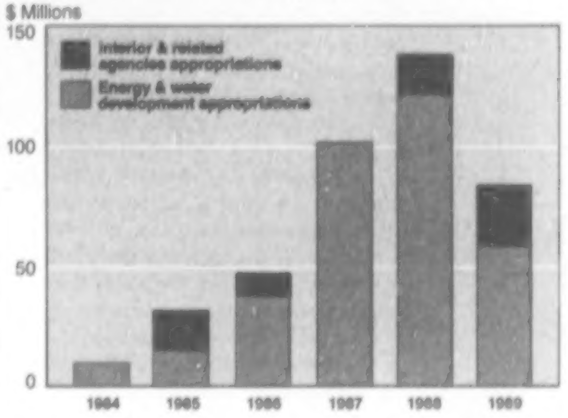
Congress wasn't the only group alienated, another Capitol Hill source points out. A year ago AAU asked its members to sign a moratorium against accepting pork-barrel funds. Ten of its 54 members refused to sign, some on general principle, others because they were already recipients of such funds.

Eventually, "It became clear that it was getting some people angry at us," says Rosenzweig. "There's no point in doing this if you can't win," he adds.

"It was more productive to use our energy and resources to seek a more constructive solution," Rosenzweig admits. So the associations regrouped and began a new two-part initiative. First, they would lobby for a new federal facilities program. Second, they would try to convince the Office of Management & Budget to change its indirect costs rules. These rules are used by academic institutions to write off facilities, supposedly to amass funds for maintenance and construction. Instead, a Capitol Hill source knowledgeable about science matters says, "They have used recovered, indirect costs for current operating costs, and have failed miserably to look to a period when they would be in need of buildings."

Universities retort that they have been severely and unfairly hampered by the indirect cost rules. The use charge, which was the only writeoff available for a long time, was predicated on an assumed 50-year life

Earmarked DOE funds increased more than 10-fold before dipping in fiscal 1989



Note: Fiscal years; interior & related agencies appropriations for fiscal 1989 are estimates based on actions to date.

for buildings. This doesn't allow for full recovery of costs, universities have long argued. In 1986 the White House Science Council agreed, and suggested a more realistic 20-year life for buildings.

Now universities can take a depreciation allowance on that portion of a nonfederally funded building used for federal research. This more advantageous method was not available to universities until recently. However, in switching from use charge to depreciation allowance, universities "incur a substantial one-time loss of recovery," says Robert Morenart, director of financial analysis and cost reimbursement for the University of Michigan.

Congress limits DOE earmarks in fiscal 1989 to nine projects

Energy & Water Development Appropriations	Interior & Related Agencies Appropriations[a]
University of South Carolina, cancer research center, $8 million	**University of Oklahoma,** energy facility, $3.5 million
Louisiana State University, Center for Advanced Microstructure & Devices, $13 million	**Northwestern University,** materials science facility, $10 million
Oregon Health Science University, $12 million	**University of West Virginia,** National Research Center for Coal & Energy, $9 million
University of Arizona, Barry M. Goldwater Center for Science & Engineering, $10 million	
Drexel University, Center for Automated Technology, $5.5 million	
Loma Linda Medical Center, Proton Beam Cancer Treatment Facility, $11.1 million	

[a] Likely to be funded.

Additionally, colleges and universities were scathed by the 1986 Tax Reform Act. "The law capped their ability to engage in tax-exempt bonding," AAU vice president John Crowley says. About 20 major institutions lost the ability to finance construction through tax-exempt bonds, he adds.

This leaves academic institutions more determined than ever to battle OMB to the end over indirect costs. They have been more successful, however, in convincing Congress of the need for a federal spending program for facilities and equipment.

At one time there were several facilities funding bills limping their way through the legislative maze. One was a section in the trade bill, which President Reagan vetoed. When that happened the Senate folded it into the National Science Foundation's fiscal 1989 authorization bill. Because the House already had a facilities provision in its NSF authorization bill, the issue could move forward.

But it did so only because of the persistent lobbying by AAU and other academic associations, says a well-placed Senate source. Joining this advocacy effort is a fairly new lobbying group called the Council on Research & Technology, or CORETECH, a coalition of research universities, companies, institutions, and trade associations.

CORETECH's executive director, Ken Kay, acknowledges Congress' right to earmark legislation. But he argues that "all members readily concede that having 525 mini-science advisers or mini-NSFs is not good public policy." Better to have a national research facilities program, he says. "It won't eliminate pork entirely, but it will create an environment in which the propensity to pork will diminish," Kay believes.

Only one stumbling block temporarily stood in the way of this lobbying effort: No one in the Administration or Congress could support a facilities bill in a tight budget. NSF director Erich Bloch repeatedly told Congress that his priorities were to support people and research first, equipment and instrumention second, and facilities last.

Still, the academic community's strong case for a facilities program impressed Congress, and a compromise was struck. There will be no money appropriated for it this year, but "Congress will establish a facilities program in the law this year and, perhaps, authorize it for 1990," the well-placed Senate source says.

The shape of the program is just becoming discernible. The provisions for it differ in the House and Senate versions of NSF's fiscal 1989 authorizing legislation, and a conference committee has yet to complete its work.

The House bill authorizes $85 million for facilities modernization in fiscal 1989, and $125 million in fiscal 1990. It sets aside 15% of the total each year for have-not universities, colleges, and research museums, those institutions that have received less than $10 million in total federal R&D funds over the two previous fiscal years. It also sets aside 10% of the total each year for institutions significantly serving minority students.

Defense Department set-asides are mainly for research projects

	$ Millions
FISCAL 1986 ($55.6 million)	
Wichita State University, aviation research	$ 5.0
University of Nevada, Las Vegas, computer research	3.5
University of Kansas, neurotoxin research	2.0
Iowa State University, research & related purposes	6.5
Northeastern University, engineering research & related purposes (in very high speed integrated circuits account)	13.5
Rochester Institute of Technology, microelectronic engineering & imaging sciences	11.1
Oregon Graduate Center, advanced semiconductor research	1.0
Oklahoma State University, research only	1.0
Syracuse University, CASE Center computer research project	12.0
FISCAL 1987 ($7.3 million)	
Mississippi State University, National Center for Physical Acoustics	5.5
Institute for Technology Development, center for advanced computation	1.8
FISCAL 1988 ($98.9 million)	
Louisiana State University, Pennington Biomedical Research Center for research on nutritional issues affecting Army personnel & dependents in peacetime	3.5
Mississippi State University, National Center for Physical Acoustics, to begin hiring qualified personnel	1.8
Unspecified recipient, to develop national bone marrow donor registry	2.1
Sandia National Laboratories, funding for Center for Compound Semiconductor Technology	10.0
Unspecified recipient, center for advanced compound & other semiconductor research	25.0
Oregon Graduate Center, to complete a program for development of semiconductor materials & devices	5.0
University of Scranton, to develop center to promote defense industry involvement in manpower training & education	7.0
Brookhaven National Laboratory & Sandia National Laboratories, to split funds, x-ray lithography research	15.0
Xavier University & Tulane University, to collaborate on developing technologies aimed at protecting health & environment from hazardous substances generated & used by DOD	16.5
Unspecified recipient in West Virginia, to design & assemble science & technology program	13.0

Source: Department of Defense

The Senate bill authorizes $80 million for fiscal 1989, and sets aside 10% for minority institutions. It has no provision for have-not institutions. But it does call for NSF to develop a comprehensive plan to scope out a facilities program and to define awards criteria, which it is to submit to Congress for approval by March 31, 1989. It authorizes $1 million for this purpose.

In ironing out the differences in the two bills, the conference committee is faced with answering many questions:

- Is there a need for NSF to draft a comprehensive plan?
- Should Congress delineate the criteria for the program, or should NSF?
- Should there be provisions for undergraduate schools?
- Should there be a set-aside for universities and colleges that are not in the top tier of recipients of federal R&D funds?
- Should there be a provision prohibiting an institution from dipping into two facilities accounts administered by, for instance, NSF and the National Institutes of Health? (NIH's authorization bill has language for funds to construct medical facilities.)

However these questions are answered, most observers believe that there probably will be money for facilities construction in the next fiscal budget. They also hazard a guess that the amount will be around $120 million.

There is hefty, though perhaps not sufficient, support for a two-part facilities program fashioned along the lines of the House bill. National Academy of Sciences president Frank Press says the first part "should be a national competition based on the quality of the proposal." In other words, funds would be allocated based on traditional merit review criteria. The second part, a set-aside, should consider proposals "based on other important criteria," he explains.

Sen. Mark O. Hatfield (R.-Ore.), who has earmarked funds for Oregon institutions, defines these other criteria. "The distribution of funds should take into account such factors as institutional need, the contribution the facility will make to economic growth and competitiveness, and the potential of the university to conduct critically needed research," he explains.

Hatfield voices the feelings of many in Congress when he says: "Peer review is appropriate for the award of funds for research projects. It may not be appropriate for awards of facilities funds."

However a facilities program is structured and whatever the criteria for awarding funds might be, there is another consideration: the eventual size of the program itself. That size hinges on the research capacity needs of the country and how much expansion the nation can afford.

Park of the American Physical Society says a study should be undertaken soon to define future needs. "My guess is that there is a need for new research capacity," he says. Another science watcher concurs: The people he speaks to believe that "when we get into the mid-1990s we will need expanded capacity."

On the other hand, AAU's Rosenzweig says, "I'm not for much expansion now because we don't have the resources. And I'm not sure we need to create a lot of new capacity to do the interesting things in science that there are to do."

Rosenzweig is expressing a sentiment that many academics believe but usually don't voice. As another observer of science matters explains, the general view is, "Unless the U.S. makes a commitment to increased

C&EN staff photo

Department of Energy photo

Clockwise from left: Silber, Hatfield, Rosenzweig, Trivelpiece

funding for research, we really don't want to build more capacity."

The issue of future capacity should spark some interesting debates, but they may never become as heated as those that have swirled around peer review versus pork-barrel science. These latter debates have an interesting history.

Congress has been dipping into Department of Agriculture coffers since 1862 when land-grant colleges were established. More recently, even as members earmarked funds for specific scientific projects, sometimes to the tune of millions of dollars, there was nary a cry from academic associations. They assumed that land-grant colleges operated under different and, by now, entrenched rules.

Even when former Speaker of the House Thomas P. (Tip) O'Neill Jr. helped one Catholic university after another, it was dismissed as no big deal, merely his Catholic charities account, says former DOE official Trivelpiece. But, when the lobbying firm Cassidy & Associates convinced Rep. Charles B. Rangel (D.-N.Y.) to earmark $5 million of DOE 1984 funds for a chemistry research facility for Columbia University, the watershed event occurred, Trivelpiece believes.

Academic pork barreling took off. And the academic associations, led by AAU, began to squeal like stuck pigs.

"The scientific community assumes that earmarked money is taken out of their hide. I don't think it is," says Trivelpiece. As one who sat in the DOE hot seat at the height of earmarking, Trivelpiece is in a good position to comment. He says that for the most part he was successful in convincing Congress to add on money for earmarked projects instead of taking it from existing or planned DOE programs. He doubts whether Congress would have given DOE additional funding if it didn't earmark projects. And, he adds, "I can't say there was any scientific project at DOE that was not done as a result of a Congressional initiative to build a facility somewhere."

DOE had to live with the political realities, but it didn't have to be happy about them. In fact, it infuriated the line-item managers. "If we had our druthers, we wouldn't be spending our money on some of these projects," says one DOE source who asks not to be named.

Because Congress never appropriated enough money to cover the full costs of DOE's basic research and the earmarked projects, "Earmarking decreased the funds available for ongoing basic energy research," says a former director in DOE's Office of Energy Research, Joel A. Snow, who is now associate vice president for research at the University of Chicago.

"Through the years, DOE has been the prime target for earmarking," says an analyst at the Congressional Research Service. "For the size of its budget, there's been surprisingly little earmarking in Department of Defense accounts," the analyst adds. However, most of the DOD set-asides are for research, not buildings as is the case with DOE, an OMB analyst explains.

A knowledgeable source who is still at DOE explains why Congress has so frequently targeted the Energy Department for "its adventurism in pork barrel." DOE's basic energy sciences is such a broad account that it can be used for a lot of things, he says. As would be expected, "Over time some earmarked projects got further away from DOE's mission," Snow adds. And this has presented management problems for the department.

From fiscal 1984 until this fiscal year, earmarked projects in DOE funds climbed from $10 million to $139 million. Earmarked funds for the upcoming fiscal year, 1989, are likely to drop dramatically to about $82 million.

Because of the budget summitry last year, the energy appropriations chairmen struck a deal: no new construction starts in fiscal 1989. As one Senate staffer put it: "People who weren't at the trough last year don't get anything this year." All the funded projects are second-year projects.

This downward trend may hold for DOE. As a House source close to the issue explains, DOE is facing a multi-billion dollar cleanup program at its nuclear fuels production facilities. The department also eventually wants to fund the expensive Superconducting Super Collider project. The number of projects vital to DOE in the future "will tend to squeeze out extra things like bricks-and-mortar earmarked money," this source says.

But this squeeze on DOE will probably force lobbyists and Congressmen to look at other accounts. Indeed, there is evidence that they already have.

Congress struck the Agriculture Department's small competitive grants program, the primary source of peer-reviewed funding for plant and animal sciences. In the past, Congress would specify which broad categories of research it wanted conducted, but it never named specific universities or specific projects. With the fiscal 1989 appropriations, this may change.

Lobbyists target 1989 Treasury, Postal Service & General Government funds

	$ Millions
SENATE APPROPRIATIONS	
University of New Mexico, Center for Southwest Research	$ 5
University of Idaho, Center for Strategic Research & Environmental Laboratory ($3 million in fiscal 1990)	4
University of Hawaii, Manoa,[a] Strategic Ocean Minerals Research Facility	10
Loyola College, Maryland,[a] Center for Advanced Information & Resource Management Studies	4
University of Utah,[a] Biomedical Polymers Center	9
HOUSE APPROPRIATIONS	
University of Hawaii,[a] Strategic Ocean Minerals Research Facility	15
University of Texas, El Paso, study and facilitate development of strategic materials technologies among industries	3

Note: Bills reported out of House and Senate; no conference scheduled as of July 8.
[a] Clients of Cassidy & Associates, Washington, D.C., lobbying firm.

About 20% of the $41 million the Senate appropriated for the competitive grants program is earmarked for four projects. A food safety consortium of four universities is to receive $2 million for research on microbial and chemical contamination of meat. The Midwest Plant Biotechnology Consortium (16 universities and 30-some companies) is to receive $2.5 million for plant sciences research. The National Center for Alternative Pest Control at the University of Arkansas is to receive $2 million to research alternative pest control. And finally, the University of Iowa, Iowa State University, and the city of Cedar Rapids are to receive $1.75 million for waste-treatment research.

The House appropriation for the competitive grants program totals only $29 million and contains one earmarked project—$2.5 million to the Michigan Biotechnology Institute to develop new products and chemicals from agricultural raw materials. A conference on the two bills is scheduled for the end of the month, and it is possible that some or all of the earmarked projects will be deleted.

Rep. George E. Brown Jr. (D.-Calif.) is incensed by this incursion into the Agriculture Department's peer review program. Earmarking, he says, "tends to place scientific considerations secondary to the ability of a given institution to lobby Congress."

The lobbying firm Cassidy & Associates has turned to Treasury, Postal Service & General Government appropriations to help three clients get facilities money. The University of Hawaii, Loyola College of Maryland, and the University of Utah are among six universities slated for Congressional largesse, if the projects survive conference.

Although one Capitol Hill science watcher believes that "the worst of the pork barreling is over," it may be too early to say. A complete scan of 1989 authorization and appropriations bills is likely to pick up many earmarks in obscure accounts. Unfortunately, the total may never be known. It is such a daunting task that the Congressional Research Service, which has tracked such earmarks since the 96th Congress, has just given up on the effort.

The pressure on members of Congress to bring jobs and prosperity home to local economies is likely to continue. Lobbyists are not going to give up lucrative business because some academics find pork barreling unwholesome.

Though a national facilities program may ease the pressures somewhat, it has to be funded to do so. And the recent history on facilities funding is not promising.

A few years back Congress approved a $20 million-a-year facilities program to be administered on a competitive basis by the Agriculture Department. Congress has yet to fund it.

So what has been a triumph for science may in the end be its despair. "The good news is that Congress finally takes a sincere interest in science and technology. The bad news is that Congress finally takes a sincere interest in science and technology," quips Trivelpiece. □

A1250-1
7/28/88

JULY 25, 1988

CHEMICAL & ENGINEERING NEWS

0511179C098 9 K AR6630SL 1DIR
CONGRESSIONAL INFO SERV-SRIDIR
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Textile Dyes

Profits return following
several lean years
Page 7

CHEMICAL & ENGINEERING NEWS

Volume 66, Number 30
CENEAR 66 (30) 1–40
ISSN 0009-2347

JULY 25, 1988

News of the Week

- **Prominent Soviet scientists and Soviet leader Gorbachev criticize Soviet scientific system and urge reforms.** Page 4
- **Tight supplies of ethylene have prompted Chevron and Exxon to build a terminal on Houston Ship Channel to import large quantities of ethylene.** Page 5
- **Based on DNA profiling, Virginia man is found guilty of rape and murder and sentenced to die in electric chair.** Page 5
- **Chemical company earnings are strong in second quarter, with Wall Street analysts recommending chemical stocks to their customers.** Page 5
- **In effort to determine the level of risk from hazardous air pollutants that society will accept, EPA proposes four alternative approaches to regulating benzene emissions.** Page 6

Cover: Photo by Jim Scruggs/
Uniphoto Picture Agency

Letters 2

Concentrates

Business 15
Government 18
Science/Technology 23

The Departments

Meetings 28
Newscripts 40

Business

Chemical employment in June was at its highest level since 1982, according to the latest data from the Labor Department. **Page 17**

Government

New U.S.-Japan science and technology agreement establishes joint R&D efforts, but contains national security and intellectual property clauses that could cause problems in the future. **Page 19**

Technology

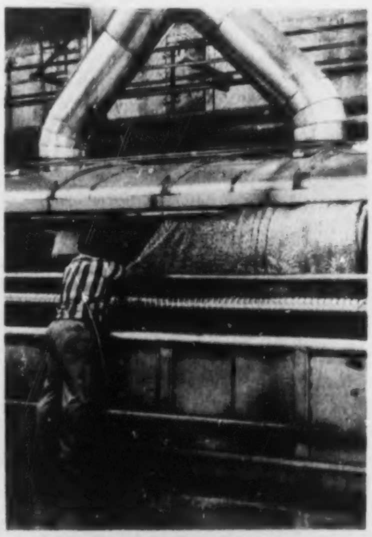
Polymer-based adsorbent that cleans up gaseous plant emissions may outperform the more conventionally used activated carbon. **Page 24**

Spider silk gene promises route to high-tensile fiber for use in bulletproof vests and similar protective garments. **Page 24**

Stable isotope labeling of emissions from coal-fired power plants could trace smoke particles over long distances and identify particle source. **Page 25**

Books

"Handbook of Research Laboratory Management" by Virginia P. White focuses on administration of large research institutions, but doesn't live up to status as a "how to" book. **Page 26**



News Focus

Following some lean years, the U.S. dye industry is once again profitable, largely because capacity is more in line with demand and the textile industry, its biggest customer, is going strong. **Page 7**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 39)

LETTERS

Symbiosis of art and science

SIR: I certainly agree with your editorial comment in the article "The Chemistry of a Stradivarius" (C&EN, May 23, page 24) that "the secret of Stradivari may not be one thing but rather many, all combined in the correct proportion." This viewpoint is very well illustrated by my own experience in collaboration with David Rubio, luthier of Cambridge. His consummate craftsmanship has been allied to a wood treatment prompted by our own examination of an authentic Stradivarius instrument [Barlow, C. Y., Edwards, P. P., Millward, G. R., Raphael, R. A., and Rubio, D. J., *Nature,* **332,** 313 (1988)].

Using this treatment, he has created more than 100 violins, violas, and cellos of superb quality, which have been avidly acquired on completion by that most demanding of clientele, professional string players. The waiting list now stretches four years hence! The whole venture constitutes an excellent example of a true symbiosis of the arts and sciences.

R. A. Raphael
Professor of Organic Chemistry
University Chemical Laboratory
Cambridge, U.K.

For the good of all

SIR: Regarding the letter from C. J. Guare (C&EN, March 21, page 4), usually good reasons exist for the use of technical terms whether in chemistry, in medicine, or in law. Such terms frequently are more definitive than common general terms, and convey more precise information to the reader/listener.

"Pro bono" does not mean "free." Pro bono is short for "pro bono publico," meaning for the public good or for the good of all. It is a service that attorneys provide to all those who need legal assistance but cannot afford it. It is not a giveaway.

"Per stirpes" is not the equivalent of "descendents." Descendents is a general term naming any and all descended from X, however remotely, without regard to degree or generation.

Per stirpes, however, refers to a right of two or more successors to a deceased predecessor to take the deceased predecessor's share of an intestate estate, not by head count, so to speak, but by equal shares of the deceased predecessor's right. Thus, if by intestate succession Y and Z would be entitled to a one-half share each in an estate of X, but Y and Z are now deceased, Y having three children and Z having one, the one-half share to Y would be divided among the three children one-sixteenth share each, and the one-half share to Z would go to his child. If a distribution was simply "by descendents," presumably by head count, each child would have received a one-fourth share. Per stirpes is much more precise.

Making things (for example, communications) more complex makes communicating more difficult only if the language used is imprecise or inaccurate.

Lyell H. Carver
Attorney and Counsellor at Law
Bartlesville, Okla.

Harm of chemicals

SIR: Robert D. Kennedy, in his guest editorial (C&EN, May 23, page 3) failed to mention an ominous development affecting the public's perception of chemistry.

Two years ago, my secretary, who lived in Northfield, Ohio, brought to the office some posters that her 12-year-old daughter had entered in a junior high school contest. The legends read, "Say No to Chemicals," "Promise Not To Use Chemicals," "Chemicals Ruin Lives," and so on.

In this school (and I'm afraid in many others), children are not equating the word "chemical" with "pollution, hazardous wastes, or some type of accident," as Kennedy suggested. Chemical, at least in the experience I cite, is a synonym for alcohol, tobacco, cocaine, and heroin. I asked the girl's mother if the contest had been conducted as part of a campaign against drugs. No, the children's specific directives had been about the harm of chemicals.

Chemistry's first goal, then, must be to educate the educators! Obviously the Pharmaceutical Manufacturers Association (or its equivalent) has done a better job in this respect than has ACS!

Saul Kaye
Evanston, Ill.

Computer-aided design

SIR: After reading the article concerning computer-aided molecular design (C&EN, Feb. 1, page 24), a reader is left with the impression that the software package, Biograf, is the only menu-driven, interactive program available. I would like to bring to the attention of your readers another package called MacroModel.

MacroModel was started in the spring of 1984 by W. Clark Still and his associates in the department of chemistry at

Better Times Ahead for U.S. Dye Producers

With production up, capacity more closely matching demand, and the textile industry, their largest customer, operating at or near capacity, dyes have returned to profitability

Marc S. Reisch, C&EN New York

"If I had to characterize the dyestuffs industry," says David S. Alcorn, vice president of the Dyes & Chemicals Division of Crompton & Knowles, "it would be to say that the profit picture has brightened for U.S. dye producers."

Only eight years ago, U.S. dye manufacturers sold dyes valued at close to $800 million, according to U.S. government data, to customers in the textiles, plastics, paper, and ink industries. In 1986, the latest year for which government data are available, sales of U.S. synthetic organic dye production had declined to $652 million. Industry overcapacity, the high volume of U.S. textile imports, and the ever-increasing burden that compliance with environmental regulations have placed on dye manufacturers have caused, in large measure, the decline.

In fact, the high cost of complying with environmental regulations will force the closure of dyes synthesis at Ciba-Geigy's Toms River, N.J., plant sometime during 1989, says Leslie G. Polson, senior vice president of the company's Dyestuffs & Chemicals Division. The largest dye producer in the U.S., Ciba-Geigy plans to build a replacement plant in St. Gabriel, La., which is scheduled to begin operating in 1990, he says.

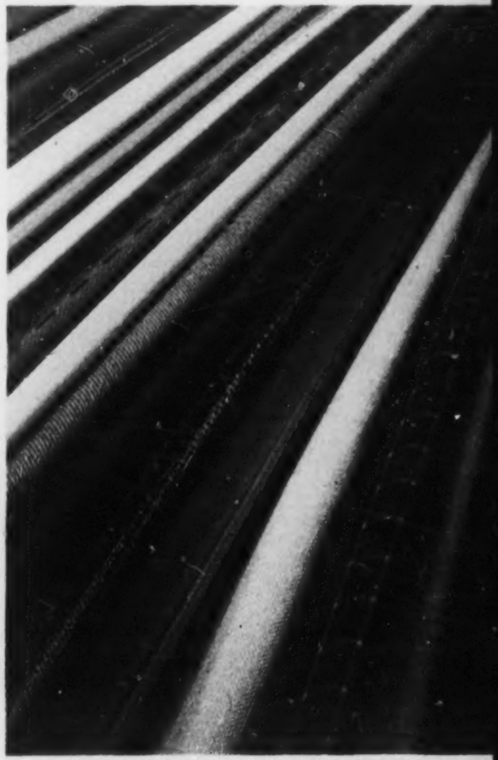
But dye makers say that better times for the U.S. dye industry are ahead because industry capacity has been severely restricted over the past few years so that it more closely matches demand. And the U.S. textile industry, which consumes anywhere between two thirds and three fourths of annual dye production, is operating at or near capacity.

The gut feeling among dye producers is that both the value and quantity of dyes produced in the U.S. increased in 1987 and will increase again this year. "1987 was a peak year for the dye business because of heavy demand for oversize garment dyes in deep bright shades," says David G. Duncan, textile dyes production manager for ICI Americas. He estimates 1987 industry sales at $700 million to $750 million and expects similar results in 1988.

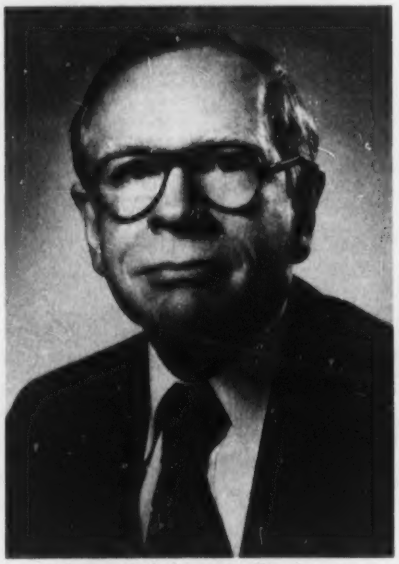
"The industry is now running at a good pace," says Heinz P. Geiss, vice president and general manager of the Colorants & Auxiliaries Division of Hoechst Celanese. "Dyes are now a profitable business," he adds, though they are "not as attractive as other specialty chemicals businesses because of the high cost of remaining in the business," stemming from inventory costs and technical service costs.

"The dye industry is at least growing now at the rate of sales increases in the textile industry," says Crompton & Knowles' Alcorn.

Although government data exist for total industry sales and individual dye class sales, sales figures for individual dye makers are difficult to come by. None of the dye makers C&EN contacted would divulge their dye production or sales figures, citing competitive and confidentiality reasons. It is clear, however, that the largest position in the U.S. dye industry is held by the U.S. subsidiaries of major European dye producers.



Textiles are biggest consumer of dyes



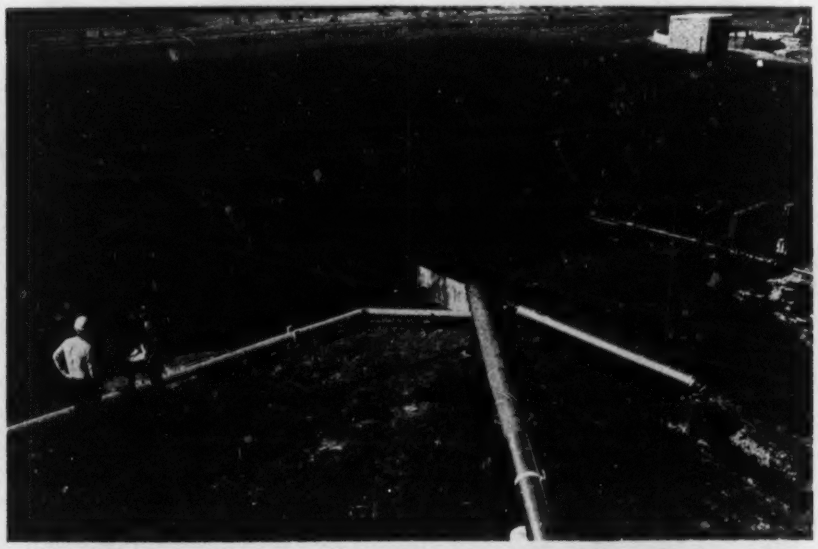
Alcorn: brighter profit picture

Industry sources say that Swiss-based Ciba-Geigy is probably the largest full-line domestic dye producer, followed by Switzerland's Sandoz and the U.S.'s Mobay, a subsidiary of West Germany's Bayer. Others with major positions in the U.S. dye industry include BASF and Hoechst Celanese. The only U.S.-based producers with significant full-line textile dye operations are Crompton & Knowles and Atlantic Industries of Nutley, N.J. The latter differs markedly from Crompton & Knowles in that it is also a significant importer of Japanese-produced dyes.

The U.S. dye industry is a highly competitive one whose complexion has changed considerably, especially between 1974 and 1983, when U.S. producers had more capacity than was realistically required. During those years eight major U.S. dye producers sold or dropped production of dyes: Tenneco Chemicals, Inmont, Allied Chemical, GAF, Harshaw Chemicals, Du Pont, Otto B. May, and American Color & Chemical. When Du Pont left the business in 1980, it probably turned off the spigot on 12% of industry dye capacity, industry sources say, and that still did not come close to putting demand and capacity in line.

Dye producers had hitched their wagons to a textile industry that seemed to be on a growth curve without end. In the heyday of the U.S. textile industry during the 1950s and 1960s, the widespread introduction of nylon, polyester, and acrylic into the apparel and home furnishings businesses created what seemed at the time unlimited expansion opportunities for textile mills and the dye makers who scrambled to produce dyes capable of putting color into man-made fiber garments and home furnishings.

Between 1960 and 1973, U.S. synthetic dye production grew from 156 million lb to the industry high of 284 million lb. Since that time, production levels have stagnated, rising and falling from year to year with the vicissitudes of the economy.



Huge lagoon is used to treat dilute waste at Crompton & Knowles dye plant

European dye makers came to dominate the U.S. market because of their low-cost position in the manufacture of the intermediates for dye production. In fact, U.S. dye makers relied heavily in the 1960s on European manufacturers for their intermediates requirements. A weak U.S. dollar in the 1970s put U.S. dye makers at a disadvantage in dye intermediates costs.

Because of their backward integration in dyes, European manufacturers have had a heavier long-term commitment to the manufacture of dyes compared with most U.S. producers. U.S. producers entered the dyes business only after World War I because of dye shortages that resulted from the war. The big European producers initially went into business in the late 19th century as developers and suppliers of synthetic dyes and from there developed their pharmaceuticals and a host of other chemical businesses. Says Gunter Thiel, Mobay's textile colorants marketing director, "We cannot afford to leave the dyestuffs business because of our inventory in it and in organic intermediates. We're here to stay."

Bayer, Mobay's parent company, has been in the dyes business since 1863, says Thiel. "We intend to stay in it at least another 125 years," he adds. But Bayer's commitment to the dyes business does not prevent it from dropping lines that are not profitable. Mobay ceased production of vat dyes at the end of 1987 and has only been selling residual quantities since, says Thiel. Mobay continues to offer basic, acid, disperse, and reactive dyes to the industry.

As a supplier to the textile business, Mobay has found that U.S. textile producers have been running strong from the second half of 1986 into 1987. This year is still a strong one, says Thiel, but some areas are spotty. Since about February and March, demand has been down for the jogging suit business, with a resulting slowdown in dyes required for these items, which are frequently acrylic or cotton items. Other areas continue to run strong, such as broadloom, mostly a nylon business, in which acid dyes are heavily used.

Peter W. Harding, manager of tex-

Dyes are separated into broad classes

Acid. Water-soluble, anionic dyes used primarily on nylon, wool, silk, and modified acrylic textiles. They consist of azo, anthraquinone, and triarylmethane compounds with a few azine, xanthene, ketone imine, nitro, nitroso, and quinoline compounds. Acid dyes are applied in the presence of an organic or inorganic acid.

Azoic. Azoic dyes are used as complementary dyes with pigments or mordant dyes on cellulosic fibers. All of these dyes contain chromophoric azo groups located between aromatic systems.

Basic. Water-soluble, cationic dyes for application to modified acrylics, modified nylons, modified polyesters, leather, unbleached paper, and inks. Acrylic, nylon, and polyester fibers are modified by incorporation of acidic groups as dye sites in the fiber to increase its ability to be dyed with basic dyes. Principal chemical classes of basic dyes are azo, anthraquinone, triarylmethane, methine, thiazine, oxazine, acridine, and quinoline. The dyes are applied in acidic dyebaths to fibers made of negatively charged polymer molecules.

Direct. Water-soluble, anionic dyes used for coloring cotton, rayon, other cellulosic fibers, leather, and paper. Dyes of this class include azo and metallized azo compounds as well as stilbenes, thiazoles, phthalocyanines, and oxazines.

Disperse. Water-insoluble, nonionic dyes used on polyester, nylon, cellulose diacetate, cellulose triacetate, and acrylic fibers. Chemical types include azo, anthraquinone, nitro, methine, and quinoline compounds. Disperse dyes are applied as aqueous dispersions, either by high-temperature pressure methods or low-temperature carrier methods.

Fiber-reactive. Water-soluble, anionic dyes containing a reactive group (such as dichlorotriazine, monochlorotriazine, or vinylsulfone) that can form a covalent bond with a compatible group on the substrate. Such covalent groups may be formed with the hydroxyl groups of cellulosic fibers such as cotton and rayon, or with the amino groups in nylon, silk, and wool.

Fluorescent brighteners. Colorless compounds that absorb incident ultraviolet light and re-emit in the blue region of the spectrum. Although not strictly considered dyes, fluorescent brighteners are used in textiles as well as in soaps and detergents and add light to a substrate. The class includes stilbene, azole, coumarin, pyrazine, and naphthalimide chemical types. Application is from solution, dispersion, or suspension.

Food, drug, and cosmetic. Synthetic organic colorants that are subject to certification by the Food & Drug Administration for use in food, drugs, and cosmetics. These dyes consist of azo, anthraquinone, carotenoid, and triarylmethane compounds.

Mordant. Mainly used to dye wool, but the class has secondary applications for dyeing silk, nylon, leather, and anodized aluminum. A mordant helps fix dye to the fiber in the form of a complex. Mordants contain chemical groups capable of reacting with salts of aluminum, chromium, cobalt, copper, and iron to give differently colored metal complexes.

Solvent. Dyes used principally in lacquers, varnishes, printing inks, and plastics. Chemical types include azo, triphenylmethane, anthraquinone, and phthalocyanine. Solvent dyes are soluble in organic solvents, which are used to disperse the dyes in the substrate.

Sulfur. Water-soluble dyes used on cotton, rayon, and cellulosic blends with nylon, acrylic, and polyester. These dyes contain sulfur both as a part of the chromophore and in polysulfide pendant chains.

Vat. Water-insoluble dyes applied in dispersions used principally for dyeing and printing cotton. Chemical classes of vat dyes include anthraquinones and indigoids.

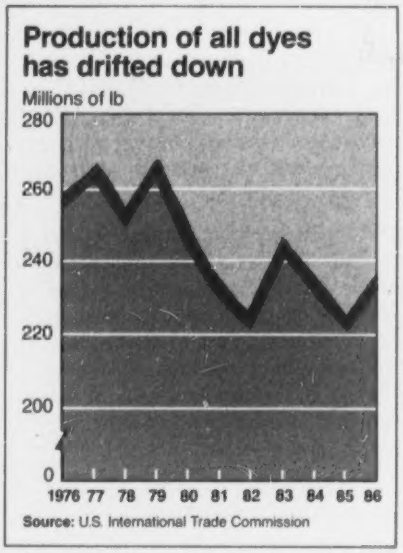
tile industry services with the consulting firm Kurt Salmon Associates, says that the domestic textile industry softened during the second quarter this year as a result of excess inventory buildups at the retail apparel level, particularly women's sportswear. He notes that women's apparel is an important sector for the dyes business and that any softness there might hurt dye makers. But he says that the softness likely will be temporary.

Aside from the vagaries of fashion and changes in demand, one of the greatest difficulties in operating a dye production facility in the U.S. is the complex regulations any such operation must satisfy. The Environmental Protection Agency must approve any manufacturer's application either to manufacture or distribute any dye in the U.S. Theoretically, when all goes well, a new dye may be approved in 90 days, says Mobay's Thiel. But when an application is challenged, the approval process can "stretch from 91 days to 900 days to nine years." Some dyes developed by parent company Bayer more than three to four years ago still do not have EPA approval.

Mobay has only one recently introduced dye. Levarfix royal blue EFR is a new reactive dye used for cotton and polyester knit goods. Thiel says that the newly introduced dye offers high tinctorial strength, high fixation and brightness, and is relatively economical.

Thiel does note that domestic dye producers have begun to see attempts by Far Eastern countries to enter the U.S. dyes market. Taiwan, Indonesia, South Korea, and China are attempting to export "garden variety dyes" to the U.S. Their cost of manufacture is generally lower than in Europe or the U.S. because of lower labor costs and either very few or no environmental restrictions.

But Thiel points out that an offshore manufacturer who is not prepared to provide a high level of technical assistance to his customer cannot essentially compete for business in the textile dyes market. Aside from the ecological assistance that domestic dye producers provide customers, they also offer quality, consistency, and efficient inventory and billing services. "This is not some-



Source: U.S. International Trade Commission

thing a fly-by-night dealer can deliver," says Thiel.

The cost of running an efficient and responsible, not to mention profitable, dye manufacturing operation in the U.S. is very high. Crompton & Knowles officials estimate, for example, that the company spends a little more than 25% of its annual dyes division capital expenditure budget on pollution abatement controls. Ciba-Geigy, whose dye operations have received the most intensive public scrutiny, also confesses that it has spent much more than 25% of its annual capital expenditures budget on environmental controls.

Ciba-Geigy's Polson acknowledges that although the company has spent enormous amounts of money trying to answer environmental objections to its dyes manufacturing plant in Toms River, its parent company in Switzerland also sustains high costs for pollution controls. The Toms River plant, where dye synthesis will be shut down, was built in 1953 and expanded in the 1960s. The company's run-in with government environmental regulations has been especially bitter and public.

In 1985, a New Jersey grand jury delivered a 33-count indictment against Ciba-Geigy and some of its employees for illegally dumping toxic wastes into a landfill and into the Atlantic Ocean (C&EN, Nov. 4, 1985, page 10). It is no wonder then that the company wants to start dyes production with a fresh slate at a new site. The company's new plant at St. Gabriel, La., will be "technologically and environmentally sound," says Polson. Its location will be at a site where Ciba-Geigy now manufactures atrazine pesticides.

Duncan: 1987 was a peak year

In the interim between the Toms River plant shutdown in 1989 and the startup of the St. Gabriel plant, Ciba-Geigy will supply its customers from inventories. It will not have to rely on increased imports from its parent company, says Polson. Ciba-Geigy is a supplier of disperse, direct, fiber-reactive, vat, acid, basic, chrome, and metal complex dyes.

"We're going to stay in the dyes business even though it's not as profitable a business as we would like," says Polson. But there has been a change of attitude toward the dyes business at Ciba-Geigy. "We looked at the dyes business for many years as a business base," he says. "We're looking at it as a hard-nosed business now. We better stand on our own feet and make money."

Polson points out that from the late 1970s to 1985, dye prices actually declined whereas the cost of just about everything else increased. "That was not a good situation," he says. "If you are going to put in the investment, you must show a return." Ciba-Geigy is putting its money into the new St. Gabriel plant because it sees the U.S. textile industry as a viable one today.

"Eight or nine years ago, we would have hesitated to make the investment in St. Gabriel," says Polson. But the textile industry has gone through a difficult reorganization period. One enormous textile firm, J. P. Stevens, has been dismantled. Burlington Mills, though still a large mill operation, is a much slimmer operation. Numerous small mills have fallen by the wayside,

About statistics for dyes

By one estimate, the U.S. consumes roughly 14% of world textile production. On a world scale then, its demand for textile dyes is proportionately lower than pharmaceuticals, for instance, for which some estimate the U.S. consumes some 40% of world output.

Given the small U.S. share of the world textile market, and factoring in the large percentage of offshore production that goes to satisfying the U.S. demand for textiles, it is easy to understand why U.S. dye makers have had anything but a rosy market.

Government statistics don't necessarily tell the full story. They are available fairly late: nine months after the calendar year they report, with no preliminary results available in the interim. Industry insiders say the statistics are further complicated because the U.S. production estimates provided by the International Trade Commission include small but significant quantities of imported dyes that have been repackaged for the U.S. market.

One close observer of industry trends, Dieter Hoecklin, Crompton & Knowles' vice president of marketing, projects actual 1987 U.S. production at 235 million lb, up from 226 million lb the previous year. Average price per lb was $3.03 in 1987, says Hoecklin, versus $2.89 in 1986.

After correcting import statistics to include only benzenoid colorants without pigments and toners, Hoecklin estimates that 63 million lb of dyes were imported and made up about 34% of the U.S. dye market valued at $1.08 billion in 1987. His 1986 estimate shows dye imports at 56 million lb, comprising some 32% of the market, which he values at $954 million.

and the survivors have invested heavily in new machinery and equipment. Much of the textile industry's reorganization occurred as imports grew, particularly in the huge apparel market. Textile imports captured about 30% of the domestic apparel market in 1980 and grew to 50% by 1987.

According to the Textile Economics Bureau, the U.S. trade deficit for garments, expressed in millions of pounds, grew 186% from 299 million lb in 1979 to 855 million lb in 1986. The man-made fiber manufactures' trade balance, excluding garments, changed from a positive trade balance of 371 million lb in 1979 to a negative trade balance of 330 million lb in 1986.

'REMALAN'
'REMALAN'

Hoechst Celanese's dyes department director Wolfgang Kretzschmar (left) and Heinz Geiss examine nylon carpet dye samples at Charlotte, N.C., laboratory

The strong dollar had been blamed for the success of imports during much of this period. Unfair trade practices have been blamed for U.S. mills' lack of success in penetrating overseas markets even as imports flooded U.S. shores. What is very clear, however, is that as U.S. textile mills lost share in their home markets, dye producers went into a tailspin: environmental regulations, overcapacity, and a concommitant growth in dye imports took their toll on the dyes industry.

It is misleading to look at capacity utilization levels and see that the U.S. textile industry is operating at or near capacity today. Numerous mill closings have restricted capacity. But dye makers now hope to benefit from a more competitive U.S. textile industry that has invested millions of dollars in the latest textile processing equipment and automation controls. "There has been an actual slowdown of textile imports in the first months of 1988," notes Polson.

And to be more competitive, U.S. textile producers are forming an alliance with dye makers in order to respond more quickly to demand. The textile industry's "Crafted with Pride" program has helped foster greater cooperation among textile producers and suppliers. The goal, already achieved in some cases, is to get all parties to cooperate in finishing items quickly so they can be shipped to retail outlets. As a result, domestic producers can use their geographic advantage over imported items, which must make the long journey from Europe or the Far East before they can be placed in a U.S. retail outlet.

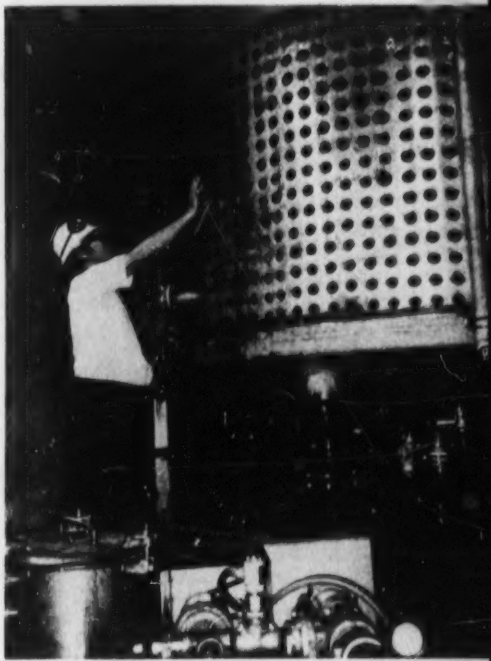
Despite its well-publicized environmental problems, Ciba-Geigy has actively sought to gain position in the U.S. dyes business. Most recently it acquired the rights to Eastman Chemical's dyes business. "Eastman added to our range of disperse dyes for custom fabrics. It was a good acquisition," says Polson. The arrangement that now exists between the two is that Eastman continues to manufacture the dyes and Ciba-Geigy distributes them. Ciba-Geigy, however, does manufacture some of the Eastman formulations in Europe for distribution there, notes Polson.

Ciba-Geigy has also introduced a new line of dyes recently. Cibacron-C is a new fiber-reactive dye. The higher reactivity of the dye means that "less of it goes down the drain," says Polson, and consequently there is less to treat and decolorize when it is discarded.

ICI Americas' Michael R. Day, business director of the Colors & Fine Chemicals Division, says that ICI's dyes business has been relatively healthy for the past few years following 1984, which he describes as a "difficult" year. "Four years ago we thought the dye business was declining at a rate of 1 to 2% a year. It's now increasing slightly on average year to year."

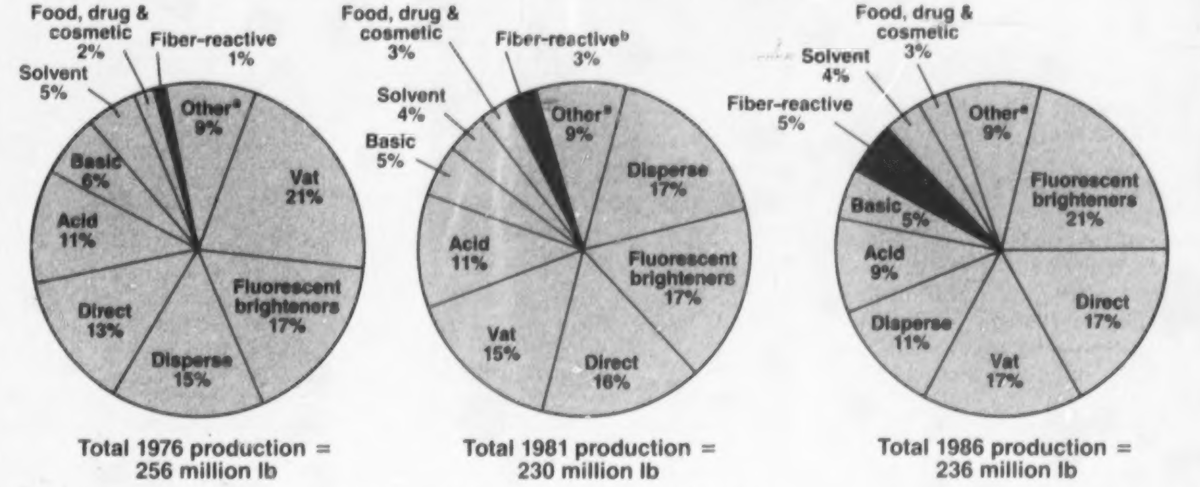
According to Day, ICI's Dighton, Mass., dye manufacturing plant "is running full out," partly because ICI is exporting its dyes to Europe in order to take advantage of the weak U.S. dollar.

ICI's strength as a synthetic dye manufacturer is in the fiber-reactive dyes, disperse, and direct dyes. To a lesser extent, it provides acid dyes as well. "The bulk of our business is in cotton dyeing. We've benefited by the trend to cotton-rich fabrics," says Day. ICI also supplies indigo, a natural plant-synthesized blue color.



Crompton & Knowles plant manager checks new conversion tank for dyes

Fiber-reactive dyes grew from 1% of production in 1976 to 5% in 1986

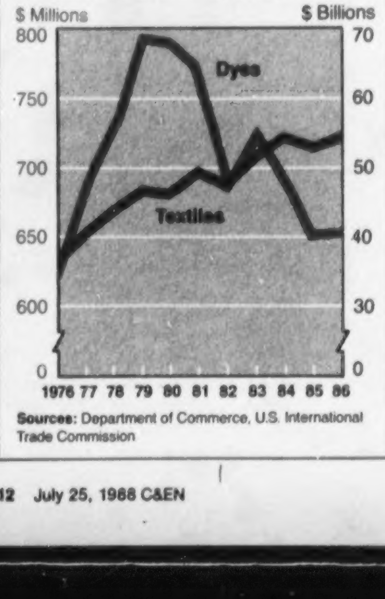


a Includes azoic, azoic diazo, mordant, and sulfur dyes. b C&EN estimate. **Source:** U.S. International Trade Commission

Like other domestic full-line producers, ICI Americas offers technical assistance to customers via its Charlotte, N.C., applications lab. Its R&D effort, however, is centered in England. Although no R&D dollar figure is available, Day says that the cost of developing a new dye runs to $500 million. That is quite high, he notes, especially since a great deal of the cost is associated with answering environmental concerns.

One industry trend that ICI is watching is the move to piece dyeing of garments. Garment manufacturers can produce any number of undyed garments that are dyed only when a retailer orders a specific color. Inventories are reduced, and popular colors can be made available more quickly. Theoretically, merchandise thus moves faster, making everybody involved in a garment's manufacture and profitable sale happier. Day estimates that piece dyeing now makes up 5% of the apparel dyeing trade and thinks it may grow to 10%.

U.S. dye sales have fallen as textile's have climbed



Sources: Department of Commerce, U.S. International Trade Commission

However, Day, as well as other dye manufacturers, cautions that the piece dyeing trend could be ruined by shoddy, uneven dyeing practices. The relatively low investment required to enter the piece dye business accounts for its recent success. However, there is a danger that unscrupulous entrepreneurs could ruin the piece dye trade if too many poorly dyed articles are turned out by dyers who are after a quick dollar, notes Day.

Cotton Inc., the U.S. government-mandated fiber marketing company supported by U.S. cotton growers, has been at the forefront of garment dyeing developments. "People in garment washing have moved into garment dyeing," says R. Mike Tyndall, manager of technical services. "It's a fashion trend business."

According to Wallace A. Blanton, director of technical services, Cotton Inc. is now working on advances in garment dyeing so that more tailored clothes, rather than the casual pieces now best suited for the process, can be piece dyed. "We're working on a resin finishing process that can be worked in at the end of the dyeing cycle," says Blanton. The aim is to achieve a final garment after dyeing that shows "less distortion of the fabric." He says that hopefully with "the proper softening and pressing techniques, we can get a tailored look."

According to ICI's Day, the company not only forecasts piece dye growth, but it also attempts to guess color demand. He admits, though, that they are not always successful. "Over the past six months, blacks and reds have been popular. No one forecasted that, and, as a result, there are some shortages in those colors."

Color forecasting is particularly difficult, says ICI's Duncan, because of what he calls "the communications explosion" today. "Young kids determine today's colors and style," he explains. Colors and styles last for 18 months at the most, he says. "Once the older generation wears it, that kills the style or color." Duncan says he watches his teenage daughter's wardrobe in order to predict color trends.

Fashion changes can put a crimp into dye production, notes Crompton & Knowles' Alcorn. Although pale shades may take up only 1% of a fabric's weight, deep shades may take up 5%. One drawback in the trend toward soil- and stain-resistant carpeting now heavily promoted in the retail market, notes Alcorn, is the tendency for consumers to chance lighter-colored carpets on the promise that the new generation carpeting will resist staining.

Even changes in fiber preferences by consumers can have a decided impact on dye class sales. With the recent decline in demand for woven polyester fabrics, Alcorn says he has noticed a dropoff in sales of disperse blue dye. A more recent drop in acrylic fiber demand will affect sales of acrylic sweater component dyes. Fiber-reactive dye sales have benefited, he notes, because of heavy consumer preference for cotton.

Crompton & Knowles has survived as the only major full-line, U.S.-based dye producer. Its specialty chemicals unit, the bulk of whose business is dye production but also includes flavors, fragrances, and organic intermediates, had 1987 sales of $152 million and an operating profit of $19 million. That division contributed 64% of 1987 corporate sales and 69% of the company's profits.

Crompton & Knowles' commitment to the dyes business is large, points out Vincent A. Calarco, chairman, president, and chief executive officer of the company. He estimates that the dyes business as a percentage of overall company sales is now roughly at 43%. "Dyes are big. They are a core business."

Thiel: in dyes business to stay

Day: growth ahead in piece dyeing

The company produces disperse, acid, fiber-reactive, direct, basic, and solvent dyes in Redding, Pa.; Gibraltar, Pa.; Lowell, N.C.; and Newark, N.J. "We see the dyes business as a true specialty chemicals business," says Calarco, in which customer service is a very important factor. The large, diversified U.S. chemical producers who left the dyes business, such as Du Pont and Allied Chemical, only derived a small percentage of their overall sales from the dyes business, Calarco points out. Crompton & Knowles has a hefty position in dyes relative to the company's overall size, he notes.

Crompton & Knowles' vision of the dyes business is not unlike that of its major European competitors. "Dyestuffs are a world market," says Alcorn. "We were the only American company to build a dyes plant in Europe 20 year ago," he points out. To learn the dyes market on its strongest competitors' turf, the company endured "five years of breakeven profits at best," he says. The company sees itself as an international dye producer. It recently took a small position in the Far East dyes market when it established a joint venture in Bangkok with Thai Ambica Chemical Co.

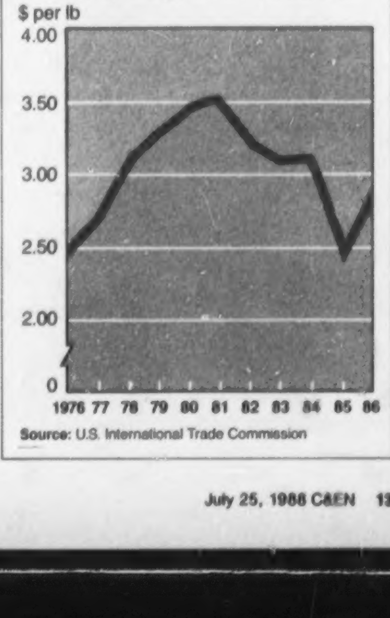
"Our approach is to focus on key market segments that are less import-sensitive," says Alcorn. Those bright spots include special lightfast dyes for automotive fabrics and carpet dyes, he notes. Within those key market segments, technical service and shorter dye runs are the focus, he points out.

An aid to Crompton & Knowles' profitability is that dye prices are rising again after the downward spiral of recent years. Calarco attributes price improvements to a 20% reduction of dye capacity in the U.S. over the past five years. Alcorn adds that another impetus for higher dye prices is the worldwide shortage of dye intermediates. Still another impetus toward price improvements is the willingness of textile customers to pay a price for the higher quality and just-in-time deliveries required as a result of the U.S. textile industry's attempt to implement the quick delivery strategy behind its "Crafted with Pride" program.

Recent new dye introductions from Crompton & Knowles include three high-concentrate liquid acid dyes for the nylon carpet trade. A new acid red, Nylanthron red S-BL, is now in limited production, too. "We think we're leaders in liquid acid dyes for carpeting," says Alcorn.

Environmental costs are a major factor in operating dye plants, notes Alcorn. They figure heavily in what he estimates is the close to $1 million cost to bring a new dye product into the market. As for dealing

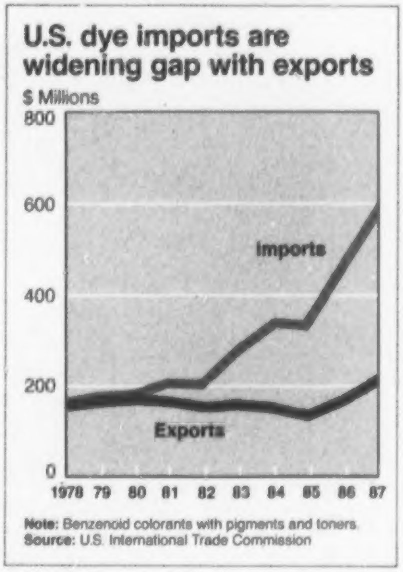
Dye prices have only recently begun to recover



Source: U.S. International Trade Commission with wastewater streams at its dyes synthesis sites, individual plants dedicated to the production of chemically similar dyes "give us a flexible base to meet government requirements," he says. Each of the four dye production plants Crompton & Knowles operates does not "have to handle multiple waste streams," which would, he says, increase effluent treatment costs geometrically.

Similar to Crompton & Knowles, Hoechst Celanese believes that the dyes industry has recovered since 1985. "A strong consumer preference for cotton, cotton blends, rayon, and bright deep shades" in the apparel business has helped, says Hoechst Celanese's Geiss. With two production facilities for vat, fiber-reactive, acid, disperse, and sulfur dyes—one in Coventry, R.I., and the other in Mt. Holly, N.C.—Geiss says that Hoechst Celanese is "one of the three largest U.S. textile dye producers." More than 80% of the dyes the company sells are produced in the U.S., he says. One new formulation, a modified acid dye line, Remalan, promises brighter shades than conventional acid colors, he says.

Hoechst Celanese is especially proud of its own color matching service for customers. Though other dye manufacturers offer quick response color, Hoechst Celanese says that customers can call with spectrophotometer readouts that are put into a color computer. "We can match most colors in 10 minutes and call back the customer with the formulation," says Geiss. The spectrophotometer "effectively reduces formulation response time from an average of one week to 15 minutes," he says.



U.S. dye imports are widening gap with exports

Note: Benzenoid colorants with pigments and toners.
Source: U.S. International Trade Commission

Calarco: customer service a big factor

Sandoz also has experienced improvements in prices and thus the margins it is able to get from dye sales, notes a spokesman for the company. The producer of acid, disperse, basic, vat, sulfur, and fiber-reactive dyes has U.S. manufacturing sites in Martin, S.C., and Mt. Holly, N.C.

Although some dye producers have noted their ability to supply liquid dyes, the Sandoz spokesman also points out that his company's new granular form fiber-reactive dye reduces dusting problems and thus promises easier handling for dye users. The granular dye line, Draimarine CDG, will be available in late summer and offers instant solubility in a dry form at higher strengths than liquid dyes, he says.

A spokesman for BASF, a producer of acid, disperse, vat, fiber-reactive, metal complex, and indigo dyes, agrees with the industry assessment that the dyes business is improving in the U.S. along with the textile business. The company produces both intermediates and dyes at Rennselaer, N.Y.

Although domestic dye producers generally agree that the industry has regained a certain measure of profitability since 1985, it does have a way to go before it reaches the nearly $800 million in sales it had in 1980. Unit pricing also has a way to go before it too reaches the $3.53 average price per lb the U.S. International Trade Commission reported in 1981.

The companies still engaged in dyes synthesis in the U.S. say they are committed to the business for the long term. Many have rationalized their production while still putting the dollars into research for newer and better dyes. They have continued to provide a high level of technical service while also working to implement the "quick response" effort that all elements of the textile industry have embraced in order to make the U.S. textile industry more competitive with overseas players.

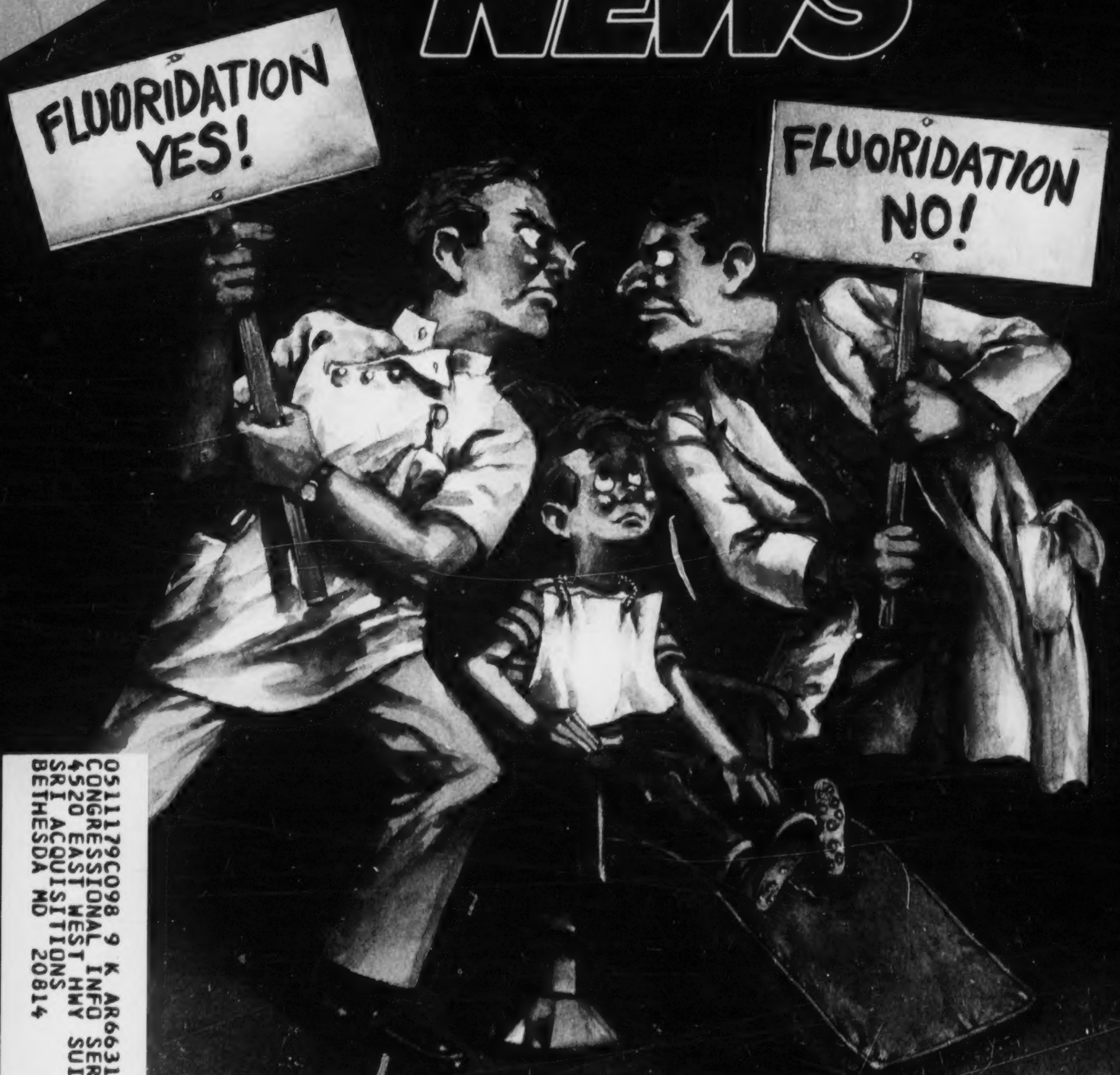
Trying to meet the burden of compliance with environmental regulations has been costly, but no one has withdrawn from dye production solely for environmental reasons. Even though Ciba-Geigy appears to have "taken it on the chin" at Toms River, it has continued to commit itself to dyes synthesis in the U.S. at its new St. Gabriel plant.

Although hoping that 1988 will be a good year for the dye industry, many producers continue to watch the textile industry anxiously. Record heat and drought have created some concern about the availability of water so necessary to textile processing and dyeing. So far, however, no severe water restrictions have compromised textile production and dyeing. A spokesman for Dalton Public Utilities in Georgia says that water restrictions there have not hurt carpet manufacturing and dyeing in that center of the U.S. broadloom manufacturing business. All broadloom plants continue to dye on a five-day schedule, except that water use is staggered so that some plants operate on Saturday and Sunday to make full use of stream flows. But the spokesman cautioned that it has been a dry year. And this natural phenomena may yet force production cutbacks for the textile producers, with resultant cutbacks in dye use. ☐

A1250-1
8/4/88

FINAL PROGRAM
ACS meeting in Los Angeles
Page 49

AUGUST 1, 1988
CHEMICAL & ENGINEERING
NEWS


FLUORIDATION YES!
FLUORIDATION NO!

0511179C098 9 K AR6631SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

FLUORIDATI

Contention won't go away
Page 26

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 31
CENEAR 66 (31) 1–156
ISSN 0009-2347

AUGUST 1, 1988

News of the Week

- **Court cases in Connecticut and Texas are introducing new complexities to the legal battle between Union Carbide and India over settlement of claims from the Bhopal disaster.** **Page 4**
- **Growing demand for ethylene and its derivatives has set the stage for plant capacity expansions in the chemical industry.** **Page 5**
- **Ring shape of benzene molecules is visible in scanning tunneling microscope images obtained by IBM scientists.** **Page 5**
- **The British government is reducing its work on fast breeder nuclear technology.** **Page 5**
- ***Nature* has denounced research results it published four weeks ago as "not reproducible."** **Page 6**

Letters **2**
Editor's Page **3**

Concentrates
Business **7**
Government **12**
Science/Technology **19**

The Departments
Software Update **25**
New Products **138**
Newscripts **156**

Business

Although U.S. chemical exports are rising strongly, chemical trade in general seems to be flaunting conventional economic wisdom. **Page 9**

Cheaper electricity and steam for the chemical process industry is being offered by small Philadelphia power company. **Page 11**

Government

Evidence needed to list a chemical as likely carcinogen in HHS annual report is debated again by industry and citizen activist groups. **Page 14**

Modified acid rain proposal calling for national cost-sharing effort is being pushed by Senators. **Page 15**

Science

Powerful new metal-chelating agents that form complexes with the more basic syn lone pairs of carboxylate ions are extraordinarily effective in binding calcium and magnesium ions. **Page 21**

Education

Six national laboratories offer new student program aimed at providing research experience during the academic year. **Page 24**

Books

"Silicon and Silicones" by Eugene G. Rochow relates history of the development of silicone materials, but omits some key data. **Page 43**

Final Program

Program for 196th ACS national meeting in Los Angeles includes listing of technical papers, general events, registration form. **Page 49**

IRIDATION YES!
FLUORID NO

Special Report

Few scientific controversies have generated as much acrimony as the one over fluoridation of water supplies. Many proponents insist that fluoridation's benefits greatly outweigh its risks, whereas many opponents view it as a potentially harmful medication imposed on the public. **Page 26**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman*: Ernest L. Eliel; *President*: Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 155)

LETTERS

CHEMICAL SAFETY

Organolanthanides plus nitrates equals dangerous mix

SIR: A recent article on cerium triscyclopentadienyl [Jacob, K., et al, *Z. Anorg. Allg. Chem.*, **556**, 170 (1988)] made by a process that we announced in 1984 in *Proceedings of the NATO ASI* (Series C, Vol. 155) prompts us to report the following.

When dry ceric ammonium nitrate (CAN) is reacted with sodium cyclopentadienyl (NaCp) under inert conditions, $CeCp_3$ and Na nitrate are produced. Normally the nitrates are filtered off. Recently, however, the solvent was removed without separating the nitrates. A violent explosion occurred when the solid reaction product mixture was heated to 75 °C. Fortunately, the damage was only material since no one was in the vicinity.

$CeCp_3$ is extremely reactive toward traces of oxygen. It blackens and deactivates instantaneously upon exposure. In the absence of atmospheric oxygen and upon heating, the oxophilicity of the element is manifested toward the nitrates in a really loud manner. Under certain conditions, mixed $Ce(NO_3)Cp_2{\cdot}NaNO_3$ complexes are obtained. They decompose with force even when a few milligrams are heated. Since there is no mention of this in Jacob's article, one could assume that these circumstances were not encountered. However, the potential of a dangerous occurrence still exists.

In view of a definite advantage in using nitrates as starting materials for preparative organolanthanide chemistry, those who might be tempted to try this route should take notice of this observation and warning that might not be restricted to cerium.

Peter S. Gradeff
Rhône-Poulenc Inc.

Coal-burning emissions

SIR: J. R. Brown et al. (C&EN, May 23, page 2) comment on the possibility that coal burning may produce significant chlorine and fluorine emissions, presumably as chlorinated and fluorinated hydrocarbons, which may consume stratospheric ozone. They provide a quantitative basis for this inference using the assumptions that "percent levels of fluorine and chlorine are common in coal" and that 0.1% is a "conservative" estimate of fluorine in coal. There is substantial literature which refutes these assumptions. Hodges et al. [*J. Inst. Energy*, **56,** 158 (1983)], in an excellent review of chlorine in coal, show levels as high as 1% for only a few selected U.K. coals. Most commercially important coals have chlorine contents less than about 0.2%, with chlorine contents less than 0.1% being very common. Chlorine contents of 1% are exceedingly uncommon. Moreover, because of the potential detrimental effects of chlorine on boiler hardware, coal users tend to specify low chlorine levels in purchasing coals. Therefore, the chlorine levels in commercially important coals tend to be lower than might be inferred from a compendium of reserve analyses.

Fluorine levels in coal are also significantly lower than the 1% Brown finds common, or his 0.1% conservative estimate. Typical levels in commercially important U.S. coals are 10 to 100 ppm, or one to three orders of magnitude lower.

Finally, the occurrence of the element at any level says nothing about its mode of emission into the environment. In the case of coal combustion, chlorine and fluorine are converted to hydrogen chloride and hydrogen fluoride and not to chlorofluorocarbons. Source apportionment studies such as those by Czuczwa and Hites [*Environ. Sci. Tech.*, **18, 444 (1984)**] indicate that coal combustion is a very minor source of chlorinated hydrocarbons compared with, for example, municipal incineration. Emissions are essentially eliminated at coal-burning units which use alkaline scrubbers for SO_2 control, since these also remove any hydrogen chloride produced by combustion.

There are unanswered questions related to the fate of halogens in coal utilization. However, it is well known that concentrations of halogens in commercially important coals are much lower than stated, that most of the halogens are converted to hydrohalic acids during combustion, and that these are readily captured by scrubbers. The use of statistical inference, based on questionable assumptions, to create the impression of a large potential problem is unwarranted.

F. P. Burke
Director, Applied Research
R. A. Winschel
Group Supervisor, Exploratory
Consolidation Coal Co.
Library, Pa.

U.S. Chemical Exports Rising, But Trade Data Pose Questions

Despite the influence of a weaker dollar, chemical imports grow faster than exports, and export prices grow faster than import prices

Earl V. Anderson,
C&EN Northeast News Bureau

The five-month trade figures recently released by the Bureau of the Census give U.S. chemical companies plenty to cheer about. They also give the industry plenty to ponder.

Through the first five months of the year, U.S. chemical exports totaled $12.9 billion, 22% higher than in the first five months of 1987. That's the cheerful news.

One of the things to ponder, however, is that U.S. chemical imports are growing faster than exports. In the January-to-May period, chemical imports, at $8.3 billion, were 28% ahead of last year's total for the five months.

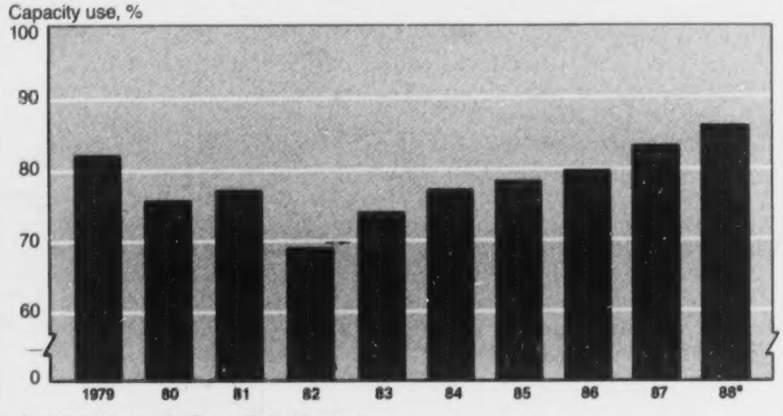
Conventional wisdom says that this is not supposed to happen. Since 1985, the dollar has depreciated about 50% against foreign currencies, according to some well-regarded yardsticks. Although the dollar has recovered some of its strength this year, it's still much weaker than it was in 1985. And a weaker dollar is supposed to help exports and hurt imports by making exports less expensive and imports more expensive.

On a total trade basis, this is exactly what has happened. U.S. exports have exploded this year. They were up about 30% (in the year's first four months) compared with only about 12% for U.S. imports. But it obviously has not happened in chemical trade.

Chemical trade, in fact, seems to be flaunting conventional economic wisdom. Chemical imports have been rising faster than exports on a constant-dollar basis. Conventional wisdom says that this should not happen.

Chemical import prices have been rising more slowly than chemical export prices. Between March 1987 and March 1988, the Bureau of Labor Statistics' (BLS) chemical export price index rose 18%. The BLS chemical import price index rose only 11%. Conventional wisdom says that this should not happen.

Chemical industry operating rates are soaring



a Based on first five months. **Source:** Federal Reserve Board

And on a real, or volume basis, chemical imports have grown faster than exports. From March 1987 through March of this year, real volume of chemical exports grew only an estimated 2.3%. Chemical imports grew more than double that, 5.5%. Again, this is contrary to conventional wisdom.

But flying in the face of conventional wisdom may not be so implausible as it may seem for U.S. chemical trade. The relative strength or weakness of the dollar is not the only factor affecting chemical trade, says Vincent J. Kamenicky, director of the office of chemicals and allied products in the Department of Commerce's International Trade Administration. Chemical trade experts in the industry agree. There are several pragmatic explanations, they say, for the seemingly odd behavior of chemical trade.

One analyst says that U.S. chemical export prices have been rising faster than import prices because U.S. exporters are keeping prices high to maximize short-term profits at the expense of long-term market share. Foreign companies, on the other hand, are keeping as tight a lid as they can on prices of products that they ship to the U.S. to maintain or even increase market share.

John S. Schwendiman, manager of strategic studies for Dow Chemical, agrees that "some of this" may be going on. But he suspects that the dichotomy in the behavior of chemical exports and imports may be more of a "mix" problem. That

← CIRCLE 12 ON READER SERVICE CARD

is, the chemical products that U.S. producers tend to export are commodity chemicals, particularly ethylene derivatives, that have enjoyed huge price increases because supplies are extremely tight. On the other hand, he says, U.S. chemical imports tend to be intermediates that must be processed further. Prices of these products have not risen so much as those of the products that U.S. companies export.

Tight supplies are making it difficult for U.S. chemical companies to increase export volume of some products even if they want to. Polyethylene, ethylene glycol, styrenics, and some vinyls are only a few examples. In some cases, producers are nearing the limits of plant capacity.

The Federal Reserve Board's capacity utilization rate for the chemical industry hit 86.2% in May, the highest it has been since 1973. The board's measure of chemical plant operating rates dropped to 68.5% during the 1982 recession, but has increased steadily ever since. Even at the beginning of last year, the chemical capacity utilization rate was only 80.9%.

Among chemical exports, plastics show steepest growth

$ Millions	Four months 1988	Four months 1987	% change
Organics			
Exports	3,025	2360	28.2%
Imports	2,311	1719	34.4
Inorganics			
Exports	1,172	869	34.9
Imports	1,146	961	19.3
Dyes, tanning & coloring materials			
Exports	231	202	14.4
Imports	381	321	18.7
Medicinals & pharmaceuticals			
Exports	1,206	1068	12.9
Imports	634	440	44.1
Essential oils[a]			
Exports	341	294	16.0
Imports	369	305	21.0
Fertilizer, manufactured			
Exports	738	635	16.2
Imports	456	319	42.9
Plastics & resins			
Exports	2,324	1691	37.4
Imports	767	626	22.5
Other			
Exports	1,244	1032	20.5
Imports	565	471	20.0
TOTAL			
EXPORTS	**10,311**	**8177**	**26.1%**
IMPORTS	**6,688**	**5211**	**28.3%**

Note: Imports are on a customs basis. a Includes essential oils, perfumes, polishing and cleansing materials. **Source:** Bureau of the Census

And when plant capacity is not the limiting factor, raw material supplies may be. Nowhere is this more apparent than in ethylene. Strong demand and plant outages have combined to make ethylene supplies extremely tight. Allocations now are common and, in some cases, force majeure is in effect. So short are ethylene supplies that Exxon Chemical and Chevron Chemical have teamed up to import the material (C&EN, July 25, page 5).

These conditions make it difficult to increase exports, Schwendiman says. Much of the chemical export market is a "spot market" and, although it is attractive, Dow and other U.S. companies tend to cater to the needs of their long-term, domestic customers first.

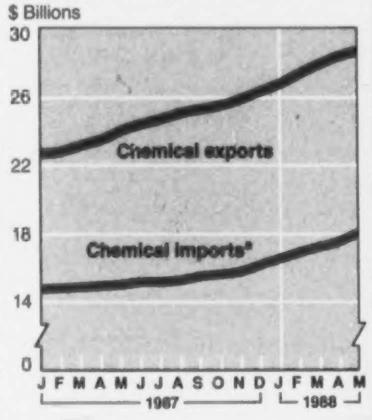
Tight markets, around the world as well as in the U.S., are what's making it possible for U.S. companies to keep their export prices high when unit prices, according to theory, should go lower as the dollar goes lower. Says Richard M. Patterson, Dow's government relations manager, "What better time to raise prices than when you're sold out?"

Strong demand and tight supply may explain why chemical export growth is high and chemical export prices are rising faster than import prices. But what about the high growth rates of chemical imports, both on a dollar and a volume basis?

One reason is the surprisingly strong U.S. economy, which tends to attract imports. But George W. Phillips, a consultant specializing in chemical trade affairs, also suspects that a lot of it has to do with the explosive growth of foreign direct investment in the U.S. chemical industry. Phillips recalls that in the 1960s and early 1970s it was U.S. chemical companies that invested heavily in overseas plants, particularly in Europe.

This overseas investment generated what became known as the "pull effect" on U.S. chemical exports. U.S. companies first exported. Then they built plants overseas. Then they found that their exports increased, not only because they often exported raw material for their foreign plants, but because their presence overseas generated a synergistic effect and increased exports of additional products.

Growth quickens for chemical imports, exports



a Customs basis. **Source:** Bureau of the Census

Phillips believes that the same thing is happening now, only in reverse. Now, it is the Europeans and others who are investing in U.S. plants. And it is European and other foreign companies whose exports to the U.S. are benefiting.

The cheaper dollar and a huge market have made investing in the U.S. very attractive for foreign chemical companies. Among the foreign giants now with sizable U.S. operations are ICI, Shell, Ciba-Geigy, and the West German Big Three of Hoechst, Bayer, and BASF. Although most of the foreign direct investment in the U.S. is European, Japanese investment is starting to grow. A case in point is Dainippon Ink & Chemicals' recent acquisition of Reichhold.

K. James O'Connor Jr., manager of international trade for the Chemical Manufacturers Association, says that the U.S. chemical industry is the most foreign-owned of any U.S. industry. In 1985, the latest year for which official statistics are available, foreign companies accounted for 27% of the U.S. chemical industry. The all-manufacturing average was 7.6%. The foreign share of the U.S.

chemical industry has probably grown by now to well above 30%.

Foreign direct investment in the U.S. chemical industry last year was about $30 billion, topping U.S. overseas chemical investment by $3 billion. On a cumulative basis, the gap between U.S. foreign chemical investment and foreign investment in U.S. chemicals has shrunk dramatically. In 1975, it was $124 billion, versus $28 billion in favor of U.S. chemical investment overseas. Last year, cumulative U.S. chemical investment overseas was $309 billion, but foreign investment in the U.S. chemical industry had grown to $262 billion.

Phillips' theory about the "pull effect" of direct investment on exports and/or imports is no doubt correct. But it is difficult to quantify. Foreign companies keep such data close to their vests. One indication, however, comes from BASF Corp., the wholly owned subsidiary of West Germany's BASF A.G. Last year, BASF Corp. imported $600 million worth of chemicals but exported only half as much ($305 million). Those figures include BASF operations in both the U.S. and Canada. They also are small compared with BASF's total sales of $4.3 billion last year. But despite these limitations, they indicate that foreign investment in U.S. chemicals definitely has a pull effect on imports.

Phillips also believes that U.S. chemical exports may be suffering a "reverse pull effect." For the past few years, several major U.S. chemical companies have been pulling back from Europe. Monsanto, Du Pont, and Union Carbide are among those that have retrenched their European operations. As a result, says Phillips, U.S. chemical exports may not be growing so fast as they would if those overseas investments were still intact.

It appears, then, that U.S. chemical trade is not defying the economic consequences of a weaker dollar, but responding to the economic realities of a unique and major international industry. It also seems certain that the factors influencing U.S. chemical trade, including foreign investment and severe shortages, are not short-term phenomena. □

Power firm offering cheaper cogeneration

O'Brien Energy Systems, a seven-year-old private power company based in Philadelphia, boasts that it can deliver relatively cheap electricity and steam for the chemical process industry.

It can do so, it says, at lower cost than if a company were to provide its own steam or electric requirements, and O'Brien can, in most cases, provide energy more cheaply than the local regulated power company. And it attempts to do so in competition with Catalyst Energy, another independent power company, as well as with subsidiaries of regulated utility firms. Most of the projects O'Brien has contracted for are in areas where electricity rates are high, such as California, Florida, and northeastern states.

But there is a hitch. O'Brien mostly installs cogeneration units with electrical generating capacities of up to 50 MW. To run economically, the power generating unit must be located near the ultimate consumer. And further, the consumer must be in a position to make use of a sustained, balanced source of energy over a period of at least 15 to 30 years, says O'Brien's Bruce Levy, vice president of marketing.

The company currently operates a small cogeneration unit at SmithKline Beckman's research facility in Conshohocken, Pa.; provides methane biogas for steam boiler operations to Atochem Polymers in Birdsboro, Pa.; and has contracts to provide Du Pont's Antioch, Calif., pigments plant with steam from a 46.5 MW cogeneration plant. Another project under contract will result in a 97 MW cogeneration plant that will provide steam for Du Pont's Parlin, N.J., photochemical plant.

About 45 employees are on the payroll of this young company. But its founder, Frank L. O'Brien III, worked for years in the family cogeneration equipment and rental business, which dates back to 1915. Separated from the other family-owned businesses, O'Brien Energy Systems went public in 1986 trading on the American Stock Exchange. Levy characterizes the company as an "energy systems developer," which does the preliminary engineering and overall design for a particular installation. It is the ultimate owner and project manager for each facility, and arranges for financing and construction.

The impetus for the company's formation was the Public Utility Regulation Policy Act passed in 1978. A product of President Carter's drive to foster greater U.S. energy independence, it provided that companies producing power from U.S. sources could compete with and even sell power to a local utility.

The cogeneration plant operating since 1983 at SmithKline's research facility provides the company with 3 MW of power from methane gas recovered on the closed adjacent Montgomery County landfill site. Waste heat from O'Brien's electrical generating unit provides SmithKline with some 13,000 lb per hour of high-pressure steam. "It's not 100% of their needs, but it's a significant amount," Levy says.

Energy pricing, he says, is "tied either to the local utility rate or the consumer's avoided cost of generating the power. And obviously," he adds, "we have to be offering it to them at a discount. We don't have a rate base as a safety net. We either sell it cheaper or go out of business."

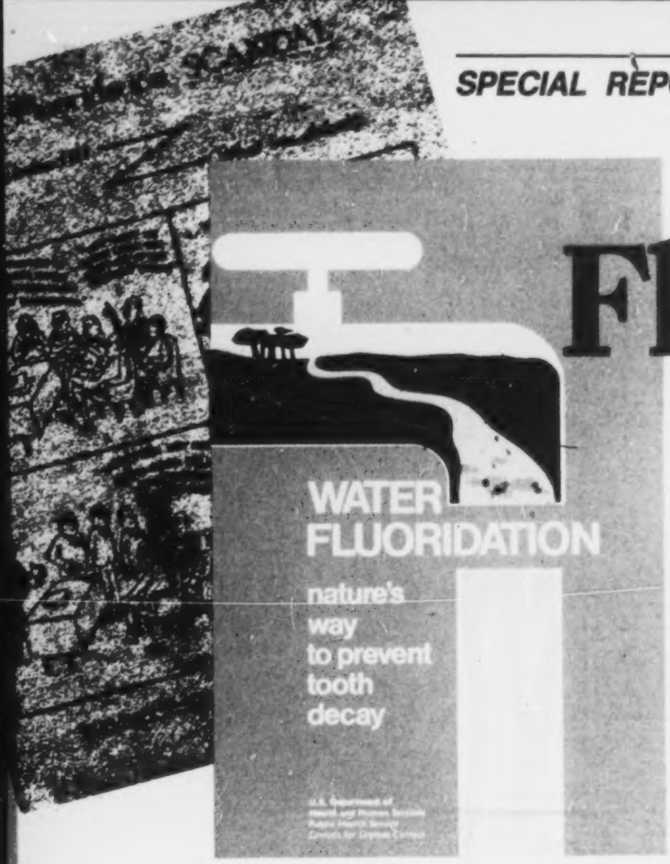
One benefit of recovering biogas at the SmithKline and Atochem sites is in preventing the gas from migrating underground and creating noxious odors or polluting underground sources of water, Levy says. Recovery also offsets the cost of gas extraction at landfills to fulfill Environmental Protection Agency requirements and provides a source of revenue for the landfill operator long after a site has otherwise closed.

At the Atochem site, O'Brien has been collecting biogas from a local landfill since 1985 and supplying it to Atochem, displacing the natural gas the company once bought to fire its boilers, Levy says.

At Du Pont's Parlin site, O'Brien plans to supply steam from a natural gas cogeneration plant, replacing an oil-fired powerhouse. Du Pont's plant manager says that the O'Brien unit will save Du Pont as much as $4 million a year.

Marc Reisch

SPECIAL REPORT



Fluoridation of Water

Questions about health risks and benefits remain after more than 40 years

Bette Hileman, C&EN Washington

The controversy over fluoridation of water supplies has raged ever since fluoride was first introduced into the drinking water of Grand Rapids, Mich., in 1945. Proponents of fluoridation say it prevents tooth decay and presents absolutely no health risks. Detractors say it causes, or may cause, serious damage to the health of some people. Many also question its effectiveness. For 43 years, there seems to have been no middle ground between the two points of view. "Neither side has given the other one rational moment," explains Jacqueline M. Warren, senior staff attorney with the Natural Resources Defense Council.

U.S. policy makers have had to make other scientific decisions, such as choices about pesticide regulation, that involve the careful balancing of risks and benefits and about which information probably is even more complex. But none has aroused acrimony quite like the fluoridation question. There is hardly any individual interested in the issue who can be classified as neutral, hardly an expert in the field who seems not to be adamantly pro- or antifluoridation. Neither side seems willing to listen to the other. Neither seems able to engage the other in constructive debate.

On the surface this seems surprising. The goal of fluoridation is unarguably worthy. Since U.S. communities began fluoridation in 1945, the prevalence of dental caries has decreased dramatically. The average number of decayed, missing, and filled permanent teeth in U.S. school age children has declined from an estimated seven to about three, according to a national survey released by the National Institute of Dental Research (NIDR) in June.

Why, then, is this issue so polarized?

According to Edward Groth III, an associate technical director of Consumers Union who wrote his Ph.D. thesis in biology on the fluoridation controversy in 1973, pro- and antifluoridationists approach the issue from completely different perspectives. "Proponents see it as a simple public health measure, effective and safe, which they need to 'sell' to the public, almost like a box of soap. Opponents tend to be much more concerned with risks than with benefits, and view fluoridation the same way society views many other 'environmental hazards'—granting that the risks may be small and uncertain, they believe society's attitude should be 'better safe than sorry.' Since any risks fluoridation may present are imposed involuntarily when a water supply is fluoridated, those risks—even if they are tiny or unsubstantiated—tend to provoke a disproportionate amount of outrage."

Indeed, anyone looking closely at the fluoridation debate can discern several separate subdebates, most with more than two distinct positions. Regarding fluoridation's benefits, proponents, such as the American Dental Association (ADA), claim it reduces the incidence of tooth decay 40 to 65% wherever it is used.

Many proponents also insist dogmatically that there is absolutely no evidence that fluoridation has had, or ever could have, harmful effects of any kind on anyone. Some argue that because most natural drinking water contains 0.1 to 0.2 ppm fluoride and nearly all

FACTS FAVOUR
FLUORIDATION
WATER
IS FOR
EVERYBODY.
FLUORIDATION
ISN'T.
Community
Water Fluoridati
The #1 Way
to Prevent Dental Decay
FLUORIDIZATION
"The Crime of the Century"
By J. A. Campbell

food has traces of fluoride, human beings are adapted to it. For many years, they have also claimed that fluoridation may reduce the incidence and severity of osteoporosis—decreased bone density in old age. Other proponents admit there are a number of recognized potential risks, but they believe there has been enough research of good enough quality to show that these risks are very remote and that the large benefits justify society's taking those risks.

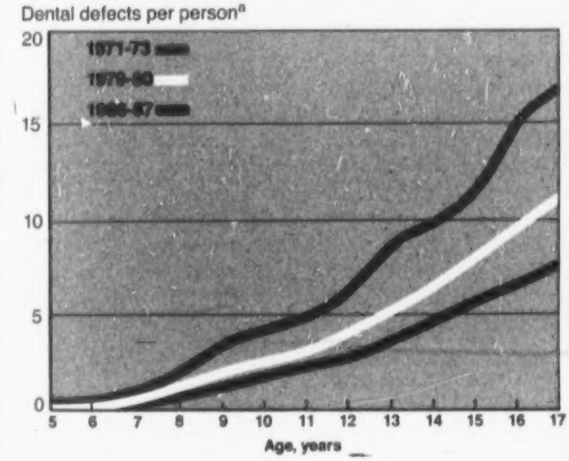
For many opponents of fluoridation, the overriding issue is a moral one of personal rights. These critics oppose fluoridation for ethical reasons. They view it as a form of medication, imposed on the public in violation of individual choice. Given that there are several other ways for people who want fluoride to consume it (for instance, in pills, mouthwashes, toothpaste, fluoridated bottled water), those who place a high value on freedom of choice argue that the state has no right to force them to consume fluoride.

Other opponents of fluoridation claim that fluoridation causes cancer, birth defects, and a large number of other ills. Such claims are frequently made by unscientific activists, who cannot support them with scientific references. But here, too, there are other less extreme opponents who argue that research has not adequately answered most of the critical questions about potential risks. Such critics, many of whom are scientists, cite hundreds of papers published in reputable journals, a collectively large body of evidence of potential hazards that, at a minimum, demands objective assessment. From the start, they also have questioned the benefits of fluoridation, claiming that its effects on tooth decay are nonexistent or greatly exaggerated.

Yet another niche in the debate has lately been filled by environmentalists, who resist being called "antifluoridation" but whose arguments tend to support the opponents. In 1986, the Natural Resources Defense Council (NRDC), one of the U.S.'s pre-eminent environmental advocacy organizations, filed a lawsuit against the Environmental Protection Agency (EPA), seeking to block the agency's proposed relaxation of drinking water standards for fluoride in natural waters. NRDC argued that EPA had inadequately considered the likely effects of fluoride on susceptible subsets of the overall population, had overlooked a great deal of scientific literature that suggested possible harm, and had not adequately evaluated a full range of possible hazards on which the evidence is incomplete or unconvincing. At best, NRDC asserted, EPA had no scientific basis for its action and more research is needed.

In general, environmental advocates believe fluoride should be investigated in the same manner many other environmental pollutants have been studied in recent years. The range of total human intake from air, water, and food must be assessed, they say. The effects on the most susceptible individuals and the levels at which these effects begin to occur should be

Tooth decay has been cut roughly ir half in U.S. since the early 1970s



a Measured in terms of average number of decayed, missing, and filled surfaces in permanent teeth. **Source:** National Institute of Dental Research

Promoters' style has fueled fluoridation controversy

The style of promotion that fluoridation's proponents have used from the very beginning probably made the issue more controversial than it need have been.

The idea of fluoridating water supplies first arose from studies of dental mottling in areas, such as communities in Texas, where the water supply is fluoridated naturally. In the 1930s, H. Trendley Dean, a dental surgeon at the U.S. Public Health Service, correlated the occurence of mottling or dental fluorosis with the fluoride content of water supplies in 345 U.S. communities. Fluorosis was most common in cities that had the highest concentration of fluoride in their water. He and his colleagues also unexpectedly found a lower incidence of dental caries in areas of endemic dental fluorosis.

Dean concluded that the fluoride content of the drinking water causes a lower rate of dental caries. He also determined that the incidence of mottling was very minor when the fluoride content was 1 ppm or lower but rose linearly at higher concentrations. From this, PHS officials decided in 1943 that 1 ppm was an optimal level at which to artificially fluoridate water supplies in temperate climates. In areas where the fluoride content exceeded 2 ppm, they recommended fluoride be reduced to a level near 1 ppm.

In 1945, PHS initially planned to conduct 10-year studies of artificial fluoridation in two experimental projects, one in New York and one in Michigan. One city in each state would be fluoridated artificially and another would serve as a control. PHS officials intended to complete these projects before deciding whether to recommend fluoridation of drinking water as a general practice for all communities.

However, two public health officers in Wisconsin, Francis A. Bull and John Frisch, quickly became convinced of the effectiveness of fluoridation and launched a nationwide campaign to persuade PHS to endorse it. Also, results from the two projects that leaked out in 1950, after the trials had been going on for five years, revealed a sharp reduction in dental caries in the fluoridated cities. As a result of this disclosure and Bull's and Frisch's campaign, PHS officials endorsed fluoridation on June 1, 1950.

Several deficiencies in research by PHS were subsequently aired at Congressional hearings in 1952 and 1957. There had been almost no careful studies to assess the possible adverse health effects of lifelong consumption of fluor-

determined. Extensive epidemiological studies should be done to see if fluoride is causing cancer or any other more subtle health effects in the general population.

Very little of the research advocated by the environmentalists has ever been done in this country and not much of it has been done anywhere else either. Since the early 1960s, most studies on the long-term effects of chronic exposure to fluoride on human biological systems other than teeth have been carried out in foreign countries.

Current status of fluoridation

Fluoridation of water supplies is largely confined to the English-speaking countries, the Soviet Union, and some Latin American nations. Of the estimated 250 million people in the world who drink artificially fluoridated water (usually fluoridated at 1 ppm), 120 million live in the U.S. (50% of the U.S. population), about 50 million in Brazil (33% of its population), and 40 million in the Soviet Union (15% of its population). Nine percent of the U.K.'s population drinks fluoridated water, two thirds of Australia's and New Zealand's, and 50% of Canada's. However, less than 1% of the population of continental Western Europe has artificially fluoridated water. For 10 years, the Netherlands tried fluoridation and gave it up in 1976 for legal reasons. (Many citizens claimed that the government had no right to add fluoride, which they considered a medicine, to the water supply, and a number of doctors observed strong hypersensitivity reactions to fluoridated water in some people.) It also was tried and then abandoned in a few towns in West Germany for legal and health reasons.

In the U.S., fluoridation is endorsed almost universally by medical and dental associations and by many scientific bodies. The American Medical Association, ADA, the U.S. Public Health Service (PHS), and every Surgeon General since the early 1950s have agreed that water fluoridated at levels of about 1 ppm is a cheap, effective, and perfectly safe way to reduce cavities.

Outside the U.S., a number of scientific groups and individuals have decided fluoridation is not safe. In France, the Chief Council of Public Health rejected fluoridation in 1980 because of doubts about whether it harms human health. The minister for the environment in Denmark recommended in 1977 that fluoridation not be allowed primarily because no adequate studies had been carried out on its long-term effects on human organ systems other than teeth and because not enough studies had been done on the effects of fluoride discharges on freshwater ecosystems. In 1978, the West German Association of Gas & Water Experts rejected fluoridation for legal reasons and because "the so-called optimal fluoride concentration of 1 mg per L is close to the dose at which long-term damage [to the human body] is to be expected."

The battle lines between pro- and antifluoridationists in the U.S. used to be very clear, with the medical and dental establishment and a great many public health officials and scientists on one side and a number of other scientists, private citizens, and members of extreme right wing groups (such as the John Birch Society and the Ku Klux Klan, who claimed fluoridation was a communist plot) on the other. Most of those who spoke out against fluoridation were, according to profluoridationists, either members of one of these idated water. Aside from their dental health, the medical condition of residents of naturally fluoridated areas had been examined superficially, at best. In one of the fluoridation trials, research plans included a study of adverse effects of artificial fluoridation on children, but none on adults. No studies focused on malnourished children and infants, despite a warning in 1952 by Maury Massler, professor of pedodontics at the University of Illinois College of Dentistry, that "low levels of fluoride ingestion which are generally considered to be safe for the general population may not be safe for malnourished infants and children, because of disturbances in calcium metabolism."

Neither PHS nor anyone else had investigated potential carcinogenic effects, effects on pregnant women, or effects on people with chronic kidney impairment or other chronic diseases. Even in the early 1950s, enough was known of fluoride's toxicity profile to identify these as important topics to investigate.

From the beginning, the movement to fluoridate water was conducted more like a political campaign than a scientific enterprise. At a meeting of state dental directors with PHS officials in June 1951, Bull recommended tactics for promoting fluoridation. "If it is a fact that some individuals are against fluoridation, you just have to knock their objections down. The question of toxicity is on the same order. Lay off it altogether. Just pass it over. 'We know there is absolutely no effect other than reducing tooth decay,' you say, and go on. If it becomes an issue, then you will have to take it over, but don't bring it up yourself."

"The minute doubt is created in the minds of the public, any public health program is doomed to failure," Bull later wrote in the *Journal of the American Dental Association.*

The political role of dentists has been emphasized throughout the history of fluoridation. In 1970, even after 25 years of fluoridation, John W. Knutson, then professor at the University of California Medical Center, advised dentists that when they discussed fluoridation with the public, they must realize that "they are propagandizing, not simply educating." This attitude, widely shared by political proponents, led early advocates to treat fluoridation campaigns as debates to be won with dogmatic assertions and attacks on the credibility of the opposition. To promoters, the debate has never been seen as a scientific search for truth.

As a result, profluoridationists prepare booklets for the public that contain highly biased information. If scientific studies are cited, only those that support their side of the argument are mentioned. Those opposed to fluoridation counter with equally biased propaganda.

radical groups or irrational, fanatic, unscientific, and fraudulent, even if they had legitimate scientific credentials.

Now, however, the lines are not so clearly drawn. Zev Remba, the Washington Bureau editor of *AGD Impact,* the publication of the Academy of General Dentistry (a group of 28,000 dentists dedicated to promoting the continuing education of general practitioners), described the situation in an editorial last year: "Today . . . the antifluoridation movement has found supporters on the left as well as the right, particularly among groups dedicated to safeguarding the environment. And as the base of support broadens, community fluoridation appears to be losing ground. In about 60% of 2000 referenda held in the U.S. since 1950, fluoridation has been voted down. A 1985 poll by the American Dental Association found that 36% of the 255 [planned or existing] fluoridation programs surveyed had been cancelled," primarily because they were rejected in referenda.

Last year, the Commissioner for the Department of Health in New York State, David Axelrod, decided to turn the department's emphasis away from fluoridation of water supplies and toward the use of topical sealants and fluoride rinses for school children. The department is still in favor of fluoridating water supplies, but is no longer funding it.

Even now fluoridation remains an issue in many cities across the U.S. Since 1983, referenda have been held on the question in well over 60 communities. In more than half of these, the majority of the people voted against fluoridation. Some referenda are held in cities without fluoridation in order to decide whether to initiate it. Others are called by opponents of fluoridation in cities where it already exists in order to terminate it. ADA and NIDR carry on a continuous campaign to persuade state legislatures to pass laws making fluoridation mandatory in all communities. So far only eight states have passed such laws, but dozens of proposed similar laws have been defeated.

Fluoridation is becoming more of an issue in developing nations as their tooth decay rates rise with the increasing use of sugar and processed food. Countries such as Brazil are now deciding whether to expand fluoridation or initiate it. In May, an international conference was held in Porto Alegre, Brazil, to assess the benefits and risks of fluoridation and help the authorities evaluate the question.

If more diverse interest groups are increasingly skeptical of fluoridation, what are the reasons? Is fluoridation just as effective as it appeared to be in the past? Have scientists uncovered new evidence of real health risks?

Benefits: a changing assessment

Originally, it was thought that the fluoride ion prevented tooth decay solely by being incorporated in tooth enamel as the teeth formed in childhood. Fluoride ingested in water or food is absorbed into the bloodstream. Part of it is excreted and the remainder is deposited in the bones and teeth. The proportion of fluoroapatite in the hydroxyapatite of developing tooth enamel is then increased:

$$Ca_{10}(PO_4)_6(OH)_2 + 2F^- \rightarrow Ca_{10}(PO_4)_6F_2 + 2OH^-$$

Fluoroapatite is less easily dissolved by mouth acids than hydroxyapatite and therefore more resistant to decay.

But today dental researchers believe two other mechanisms are just as important or more so. A number of factors, including fluoride ion, influence a constant exchange of ions across tooth surfaces. Bacteria in the mouth convert sugar to acids, which cause demineralization of tooth surfaces. Demineralization and remineralization take place constantly on the surface. When the pH of the surface drops, calcium and phosphate ions pass from the enamel into the plaque, but if the pH becomes neutral, these ions may redeposit themselves into the enamel. Fluoride ions in the plaque inhibit the bacterial conversion of sugar to acids and thereby help maintain higher pH levels, allowing remineralization to occur. Therefore, the fluoride ions in saliva and plaque may be just as important in preventing tooth decay as the ions in blood—and perhaps just as easily provided by toothpaste as water.

A third mechanism by which fluoride may prevent decay involves incorporation of fluoride into the remineralizing enamel surface, making it more resistant to decay.

For many years, most dentists believed that fluoridation of water supplies reduced tooth decay about 50 to 65%. These figures were based primarily on four studies during the early years of fluoridation: in Grand Rapids, Mich.; Newburgh, N.Y.; Evanston, Ill.; and Brantford, Ont. But a great deal of evidence indicates that water fluoridation reduces dental caries much less. In fact, some research suggests little or no reduction at all.

Most major developed countries do not fluoridate their water supplies

Country	Population (millions)	Percent of population drinking artificially fluoridated water
Albania	3.1	0%
Australia	16.1	66
Austria	7.6	0
Belgium[a]	9.9	0
Bulgaria	9.0	0
Canada	25.9	50
Czechoslovakia	15.6	20
Denmark	5.1	0
East Germany	16.6	9
Finland[b]	4.8	1.5
France	55.6	0
Greece	10.0	0
Hungary	10.6	0
Ireland	3.5	50
Italy	57.4	0
Japan	122.0	0
Luxembourg	0.4	0
Netherlands[c]	14.6	0
New Zealand	3.3	66
Norway	4.2	0
Poland	37.7	4
Portugal[a]	10.3	0
Romania	22.9	0
Spain	39.0	Less than 1%
Sweden	8.4	0
Switzerland	6.6	4
U.K.	56.8	9
U.S.	243.8	50
U.S.S.R.	284.0	15
West Germany[d]	61.0	0
Yugoslavia	23.4	0

a One experimental treatment plant now discontinued. **b** One small experimental treatment plant. **c** Discontinued in 1976 after 23 years of experiments. **d** Discontinued in 1978 after 18 years of experiments.

Alan S. Gray, former director of the Division of Dental Health Services for the British Columbia Ministry of Health, finds, for example, that the average number of decayed, missing, and filled permanent teeth in British Columbia, where only 11% of the population uses fluoridated water, is lower than in parts of Canada where 40 to 70% of the people drink fluoridated water. School districts in the province with the highest percentage of children with no tooth decay are totally unfluoridated. These differences could, of course, be caused by factors other than fluoridation.

Tooth decay is a complicated process, influenced by many factors, including diet, oral hygiene, dental care, genetic predisposition, geochemical factors, and possibly other trace elements, such as strontium, as well as fluoride in the water supply. Additional factors that may affect decay rates are the use of fluoridated toothpastes or topical rinses and the presence of fluorides in foods. Most people whose diet includes little sugar and few processed foods have very low rates of tooth decay. In those few developing countries in which only small amounts of sucrose and refined foods are eaten, decay rates are often lower than in the developed nations. And if other factors are equal, districts in the developed world where the socioeconomic status is higher generally have less decay.

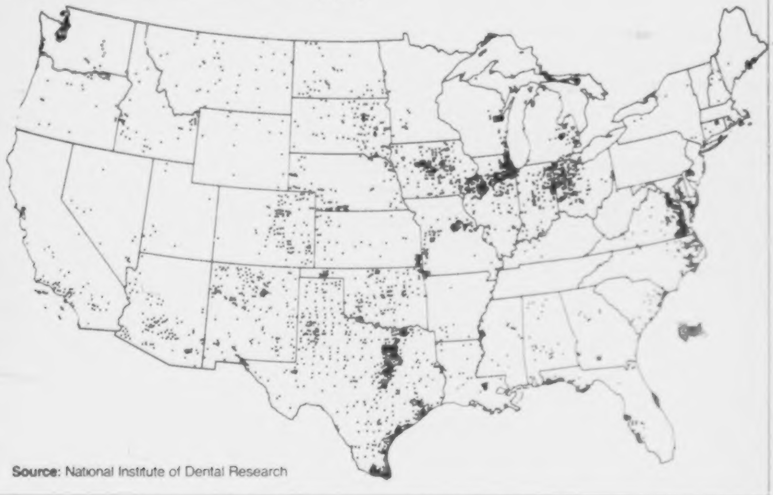
Therefore, comparisons between fluoridated and unfluoridated districts that don't adequately take such factors into account can be readily confounded. None of the early epidemiological studies controlled very well for most nonfluoride variables, so many scientists today have come to regard them as only part of the evidence one must consider to assess the size of fluoridation's benefits.

One recent development that bears on the question is the widespread observation that tooth decay rates in the U.S., Canada, New Zealand, Australia, and in all countries of Western Europe have declined greatly during the past 40 years. Mark Diesendorf, an applied mathematician and health researcher in the Human Sciences Program at Australian National University and an expert in research design, has found, by comparing results from about 24 studies of unfluoridated districts in eight countries, that reductions in dental caries are just as great in nonfluoridated as in fluoridated areas. In Queensland, which is primarily unfluoridated, the rate of tooth decay is as low as it is in the fluoridated districts of Australia.

Diesendorf concludes from such data that fluoridation of water supplies may not be nearly so important in preventing tooth decay as many authorities believe. Some of the decline in dental caries in unfluoridated areas might be explained by the introduction of fluoride toothpaste, tablets, and mouthrinses,

H. Trendley Dean's studies during 1930s and 1940s established relation of fluoride level in drinking water with tooth decay and dental fluorosis

Many U.S. communities have 0.7 ppm or more natural fluoride in their water supply



Source: National Institute of Dental Research

he says, but decay rates began to fall in many of the nonfluoridated regions long before these were available. He believes that changes in nutrition, oral hygiene, and possibly the immune status of the population may explain part of the decline.

A number of researchers in the U.S. have reported similar findings. Stanley B. Heifetz and coworkers at NIDR note in the April issue of the *Journal of the American Dental Association* that "the current reported decline in caries in the U.S. and other Western industrialized countries has been observed in both fluoridated and nonfluoridated communities, with percentage reductions in each community apparently about the same."

Robert L. Glass of Forsyth Dental Center, Boston, noted that in 1965, after more than 20 years of fluoridation, counts of decayed, missing, and filled permanent teeth for Grand Rapids, Mich., and Newburgh, N.Y., were only minimally different from the average for the entire U.S., which then was about 33% fluoridated. Because he had expected nonfluoridated areas to have higher decay rates than fluoridated ones, and to therefore raise the average for the entire U.S., he concluded that the U.S. average had not been determined correctly. It is also plausible, however, that the effects of fluoridation had been overstated, or perhaps that Grand Rapids and Newburgh had exceptionally high levels of decay before fluoridation began.

Other recent reports indicate that fluoridated areas have lower decay rates than unfluoridated areas, but by much less than the alleged 50 to 60% difference. A 1983 study of tooth decay in 10 cities by the Robert Wood Johnson Foundation and Rand Corp. found that fluoridated cities have roughly one third less decay, which means that average 12-year-olds in fluoridated cities have about 0.6 fewer cavities than those in nonfluoridated cities. Gray points out that decay reductions of even 33% taking place today, when average base decay rates are at such a historically low level, do not mean as much as they did in the past.

Research conducted in the 1930s and 1940s in the U.S. showed that the incidence of dental caries was reduced most effectively where the natural fluoride level of the water supply was 1 ppm or above. But five studies in India, Sweden, Japan, the U.S., and New Zealand do not support this trend. In the Japanese study, for example, children in an area with 0.3 to 0.4 ppm fluoride in the water have the lowest decay rates; above and below this range, caries prevalence increases rapidly. These results contradict a central tenet of the fluoridation theory—that the ideal fluoride level, producing low decay rates with minimal damage to the teeth, is about 1 ppm.

At NIDR, officials are reassessing the decay reductions that can be attributed to fluoridated water. Herschel S. Horowitz, formerly chief of the clinical trials section of the caries prevention and research program, says that recent studies suggest that reductions are not so large as the 50 to 60% indicated by early studies. NIDR scientists are trying to determine what they call a "new baseline." Whatever the ultimate result, a consensus seems to have emerged that the promise of "two thirds less tooth decay" with fluoridation is no longer realistic, if indeed it ever was.

In a similar vein, the economic benefits of fluoridation appear to have been exaggerated. NIDR states that every dollar spent on fluoridation, which costs only 20 to 50 cents per person per year, reduces dental costs $50. NIDR assumes that fluoridation reduces cavities some fixed percent, such as 40%, and then multiplies the total number of cavities theoretically prevented by the average cost of filling one cavity. But when the actual costs of dental care delivered in similar cities are compared, residents of fluoridated cities seem to reap no economic benefit from fluoridation. In one study, reported in a February 1972 article in the *Journal of the American Dental Association,* the cost of dental care in five unfluoridated cities in Illinois was compared with costs in five similar cities with naturally fluoridated water. Even though dentists' fees and the nature of treatments in the two groups of cities did not differ significantly, the cost per patient and the average number of visits to the dentist per year were greater in the fluoridated communities.

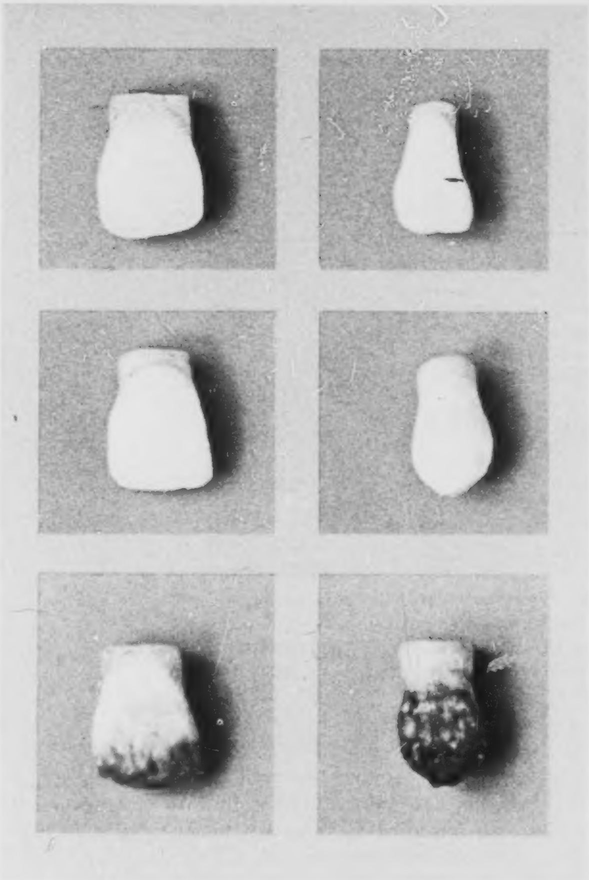
Proponents also are trying to show that fluoride can be used to alleviate the symptoms of osteoporosis, and therefore that people living in fluoridated areas may be helped by the excess fluoride they are accumulating in their bones. Because excess fluoride produces osteosclerosis (denser bones), patients in numerous clinical trials have been given and are still being given large doses of fluoride (60 to 80 mg per day) as treatment for osteoporosis. So far this method has produced no definitive beneficial results. In a 1987 review of fluoride therapy for osteoporosis, Louis V. Avioli, professor at the Washington University School of Medicine, concludes: "Sodium fluoride therapy is accompanied by so many medical complications and side effects that it is hardly worth exploring in depth as a therapeutic mode for postmenopausal osteoporosis, since it fails to decrease the propensity toward hip fractures and increases the incidence of stress fractures in the extremities." FDA has not approved the use of fluoride for osteoporosis.

Health risks: more questions than answers

The physiological effects of fluoride on the human body range from those about which there is a great deal of scientific information to those that are less certain, but about which there is some credible evidence, to those that are almost purely speculative. Even the effects for which there is good information are controversial. Some scientists define them as health effects, but others consider them as merely cosmetic or conditions without negative implications for health.

More than any other area of fluoride research, scientific debate over potential health hazards has been polarized by the political controversy over fluoridation. Does a study show adverse effects? Is certain evidence relevant to an assessment of the safety of fluoridation at 1 ppm? The answers experts give differ, depending on whether the experts favor or oppose fluoridation. The political schism over the measure has dominated scientific discourse on the topic, almost totally blocking consensus over what the evidence of adverse effects means—or in some cases, even over whether such evidence exists.

The effects of fluoridation that have been studied the most are dental fluorosis (mottling of teeth), skeletal fluorosis, kidney disease, hypersensitivity reactions, enzyme effects, genetic mutations, birth defects, and cancer. The information about dental fluorosis is clearest and least controversial. Knowledge of skeletal fluorosis is extensive, but not at all complete. The information about fluoride and kidneys is partly established and, in part, almost purely speculative owing to a lack of research. Hypersensitivity reactions have been studied thoroughly by only a few investigators and many important issues remain unresolved. Birth defects and cancer have been much discussed, but evidence in these areas is the most uncertain.



Fluoride in drinking water may affect teeth to various degrees during the years of tooth formation, depending on the degree of exposure and individual sensitivity. Compared with a normal tooth (top row, left), a tooth with questionable fluorosis (top row, right) shows no clear evidence of change, for instance, and one with very mild fluorosis (middle row, left) only has small white flecks. However, a tooth with mild fluorosis (middle row, right) has chalky white areas; moderate fluorosis causes yellow or brown mottling (bottom row, left); and a tooth with severe fluorosis (bottom row, right) is heavily stained, pitted, brittle, and susceptible to fracture

Copyright Ingolf J. Møller, Copenhagen

Though profluoridation statements almost always claim that all risks have been fully investigated and found to be groundless, in fact a number of important unanswered questions remain about each of these health risk areas. The 1977 National Academy of Sciences report "Drinking Water and Health" recommends research in 11 different areas. Even though more than a decade has passed, research in only three health effects areas, dental fluorosis, cancer, and birth defects, has been funded by the federal agencies responsible for research on fluoride (PHS and EPA).

The fluoride ion is unusual among trace elements in water or food because the same range of human exposure to fluoride ion that can produce beneficial physiological effects can also produce harmful effects. For most trace elements, such as chromium, manganese, and zinc, beneficial and harmful ranges of exposure differ greatly.

In 1962, PHS set fluoride levels of 0.7 to 1.2 ppm in drinking water as the ideal range to prevent dental caries with minimal dental fluorosis. The lower level was suggested for hot climates and progressively higher levels were prescribed for cooler regions, because average water consumption varies with temperature. Natural fluoride levels exceeding twice the ideal for the climate, PHS said, constituted grounds for rejection of the water supply, but it had no power to force communities to remove excess fluoride.

In 1975, EPA took over PHS's responsibility for regulating contaminants in drinking water and, in 1986, relaxed the maximum contaminant level to 4 ppm for all climates. Communities that add fluoride to drinking water still do so according to the old PHS formula. But communities with naturally fluoridated water are not required to remove fluoride unless the level exceeds 4 ppm. Some of the potential adverse health effects, however, may occur at levels of about 1 ppm and above and are both more pronounced and more widespread at levels near 4 ppm.

In humans, 98% of the fluoride ingested in water is absorbed into the blood from the gastrointestinal tract. The fluoride diffuses to the body's cellular tissues and most of it is deposited in the bones and teeth or excreted by the kidneys. The aorta is the only other tissue that normally accumulates significant amounts of fluoride, mainly in calcified deposits. The amount stored in bones and teeth varies depending on the age of the subject. According to NIDR's Heifetz and Horowitz, in children more than 50% of an ingested dose of fluoride may be deposited in bone, but in adults only about 10% is stored there. As with teeth, fluoride is deposited in bone by simple ionic exchange with the hydroxyl groups of hydroxyapatite. It also is removed from bone, though at a slower rate than it is deposited. If the intake remains constant, the level of fluoride in the bones increases linearly with age.

The most obvious and common effect of fluoride on humans is dental fluorosis. This occurs only if children drink fluoridated water, receive fluoride supplements, or ingest significant fluoride from other sources (like toothpaste) during the years of tooth formation. In excessive amounts, fluoride interferes with the normal function of the enamel-producing cells in the jaw, called ameloblasts, in laying down amelogen matrix and in the mineralization of this enamel matrix. (Amelogen is a collagenlike material that forms the structural foundation and framework upon which calcium and phosphate are deposited, giving rise to tooth enamel.)

The late H. Trendley Dean, a dental surgeon at PHS, defined five degrees of dental fluorosis: questionable, very mild, mild, moderate, and severe. In the questionable form, evidence of fluorosis is uncertain; in the very mild form, teeth have small white specks; in the mild form, teeth have chalky white areas; in the moderate form, they may have yellow

Some studies indicate that dental fluorosis is increasing

Scientists disagree over whether the incidence of dental fluorosis is increasing in the U.S. as more children drink fluoridated water and use fluoride supplements, toothpaste, mouth rinses, and topical applications during the years of tooth formation.

Dennis Leverett, chairman of the department of community dentistry at the Eastman Dental Center in Rochester, N.Y., claims that the prevalence of dental fluorosis today in communities with fluoridated water is twice the level that H. Trendley Dean, a dental surgeon in the Public Health Service, reported in 1942 from his studies of communities with the same level of natural fluoride in their water supply. Leverett fears that if additional studies substantiate his findings, fluoride levels in supplements, toothpastes (most of which contain 1000 ppm fluoride), and water may need to be reassessed. He reasons that the increase in fluorosis may result from the increased use of fluoridated toothpastes, supplements, and perhaps from higher levels of fluoride in the food chain. Today, nearly all bottled drinks and canned foods in the U.S. are processed with fluoridated water. Should further studies confirm Leverett's conclusion, it would validate a warning that has been sounded by scientific critics of fluoridation for at least 25 years.

In contrast, William S. Driscoll, acting chief of the disease prevention and health promotion branch at the National Institute of Dental Research (NIDR), and his coworkers report that surveys in 1980 "suggest that no important changes in the prevalence and severity of fluorosis have taken place" since Dean's studies. However, Driscoll did find eight children with either moderate or severe fluorosis in a community with a fluoride level of 1 ppm. In the 1930s, Dean generally found no children with advanced forms of fluorosis in the many towns he surveyed with 1 ppm natural fluoride in the water supply.

In 1985, Stanley B. Heifetz, Driscoll, and their coworkers at NIDR surveyed the same areas in Illinois they had surveyed in 1980. The prevalence of fluorosis in eight- to 10-year-olds changed little between 1980 and 1985. But among 13- to 15-year-olds, the researchers note a greater prevalence and severity of fluorosis in 1985 than in 1980. In 1985, only 71% of tooth surfaces were fluorosis-free in a community with 1 ppm fluoride, compared with 89% in 1980. In a community with 4 ppm fluoride, fluorosis had become so prevalent that 93% of the visible tooth surfaces showed some signs of the condition, compared with 76% in 1980.

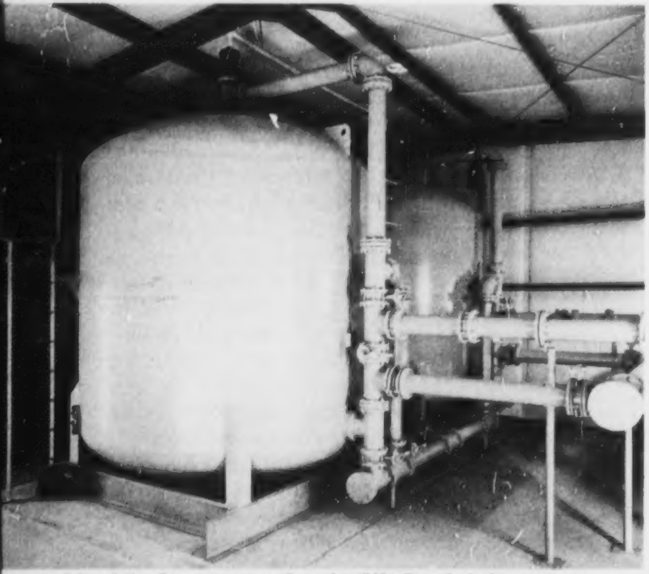
Several studies indicate, therefore, that the prevalence of dental fluorosis is rising, particularly at fluoride levels of 1 ppm, a level at which objectionable fluorosis was extremely rare in the 1930s. But the populations studied are so limited that it is difficult to determine how much fluorosis is increasing.

and brown stains; in the severe form, depending on the amount of fluoride ingested, they are pitted, brittle, and susceptible to fracture. Severe fluorosis not only produces unattractive teeth but also may increase the risk of tooth loss because it destroys parts of the protective enamel.

According to a recent study conducted by NIDR in areas with different concentrations of naturally occurring fluoride in their water supplies, 2% of the children developed moderate or severe fluorosis and about 12% developed very mild and mild fluorosis at 1 ppm—the level of fluoride that NIDR considers ideal. But at 4 ppm, the maximum fluoride level EPA now allows in the U.S., 7% had moderate and 23% severe dental fluorosis (approximately the same total fraction of objectionable fluorosis Dean noted in the 1930s in 4-ppm areas). Since this study was very limited, the percents of fluorosis may not be representative of the country as a whole.

But if the fraction of children subject to moderate and severe dental fluorosis is anywhere near 1 or 2% in most areas with 1 ppm fluoride, a great many children are at risk of developing disfiguring degrees of fluorosis. And, of course, a large fraction of children in the 4-ppm areas would develop noticeable fluorosis. To avoid dental fluorosis, "children under five years of age should drink water diluted with a fluoride-free source in communities with 4 ppm fluoride," NIDR's Horowitz says.

There seems to be little controversy over what levels of fluoride in water cause moderate and severe dental fluorosis. Scientists disagree, however, about whether moderate to severe dental fluorosis is a health effect. This may seem like an academic issue, but under the Safe Drinking Water Act, EPA is required to set recommended maximum contaminant levels (RMCLs) that will prevent known or anticipated adverse health effects with an adequate margin of safety and to set the maximum contaminant levels as close to the RMCLs as is feasible. (The RMCLs are unenforceable goals; the maximum contaminant levels are enforceable standards.) A special committee convened by the Surgeon General in 1983 to guide EPA in setting its fluoride standard wrote in the first draft of its report that moderate to severe dental fluorosis per se is a health effect. The second draft, presented to the Surgeon General in September 1983, said that moderate to severe dental fluorosis is only a cosmetic effect—the position long held by political advocates of fluoridation. This rationale allowed EPA to ignore dental fluorosis in setting the RMCL for fluoride.



Municipal treatment plant in Gila Bend, Ariz., uses selective adsorption with activated alumina to reduce excess fluoride level in drinking water

Skeletal fluorosis

One solidly established concept in environmental health is that the effects of toxic agents fall on a continuum of biological change, ranging from undetectable effects at the lowest levels of exposure to severe health damage at very high doses. As exposure to an agent increases, the first detectable effect may be a subtle biochemical change, such as a decrease in the activity of an enzyme. At somewhat higher doses, measurable changes in some physiological functions may occur, but these often are not linked to clear symptoms or adverse effects, and may not be harmful. But as dosage increases, adverse effects begin to appear—at first mild ones, then moderate ones, and finally severe ones.

Most environmental health experts believe that the subtlest detectable effects—those with no outward symptoms, which are not clearly harmful—should be considered "precursors" of more serious effects. By this logic, people who show such subtle changes should be considered at risk for more serious effects if exposure continues.

Skeletal fluorosis, a complicated illness caused by the accumulation of too much fluoride in the bones, has a number of stages. The first two stages are preclinical—that is, the patient feels no symptoms but changes have taken place in the body. In the first preclinical stage, biochemical abnormalities occur in the blood and in bone composition; in the second, histological changes can be observed in the bone in biopsies. Some experts call these changes harmful because they are precursors of more serious conditions. Others say they are harmless.

In the early clinical stage of skeletal fluorosis, symptoms include pains in the bones and joints; sensations of burning, pricking, and tingling in the limbs; muscle weakness; chronic fatigue; and gastrointestinal disorders and reduced appetite. During this phase, changes in the pelvis and spinal column can be detected on x-rays. The bone has both a more prominent and more blurred structure.

In the second clinical stage, pains in the bones become constant and some of the ligaments begin to calcify. Osteoporosis may occur in the long bones, and early symptoms of osteosclerosis (a condition in which the bones become more dense and have abnormal crystalline structure) are present. Bony spurs may also appear on the limb bones, especially around the knee, the elbow, and on the surface of tibia and ulna.

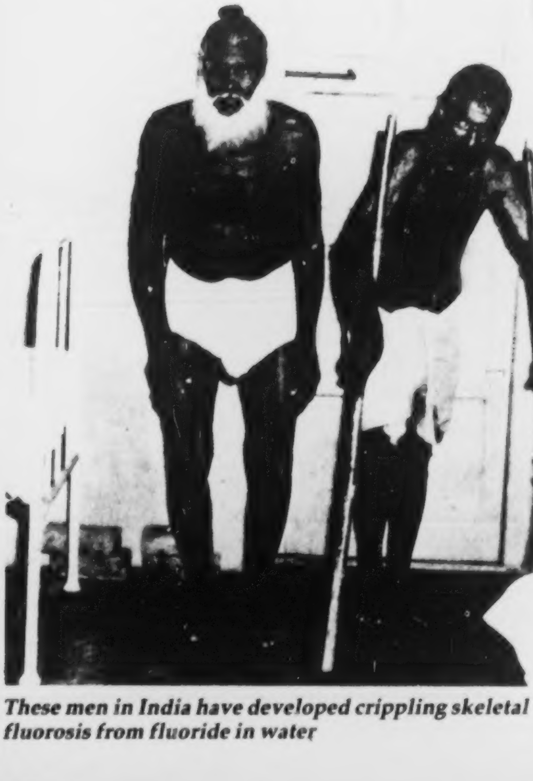
In advanced skeletal fluorosis, called crippling skeletal fluorosis, the extremities become weak and moving the joints is difficult. The vertebrae partially fuse together, crippling the patient.

Most experts in skeletal fluorosis agree that ingestion of 20 mg of fluoride a day for 20 years or more can cause crippling skeletal fluorosis. Doses as low as 2 to 5 mg per day can cause the preclinical and earlier clinical stages.

The situation is complicated because the risk of skeletal fluorosis depends on more than the level of fluoride in the water. It also depends on nutritional status, intake of vitamin D and protein, absolute amount of calcium and ratio of calcium to magnesium in drinking water, and other factors.

In parts of India, China, Africa, Japan, and the Middle East, large numbers of people have skeletal fluorosis from drinking naturally fluoridated water. In India about a million people have this disease. Most of the victims live in areas where the water fluoride level is 2 ppm or above, but some cases are found in communities with natural fluoride levels below 1 ppm.

In the U.S., more than a dozen cases of skeletal fluorosis have been reported. Some have occurred at high fluoride levels, others at levels lower than 4 ppm when



These men in India have developed crippling skeletal fluorosis from fluoride in water

EPA union's attempt to join lawsuit opposing fluoride standard was rebuffed

In an unprecedented move, the Environmental Protection Agency's union of professional employees, Local 2050 of the National Federation of Federal Employees, attempted to file an amicus curiae brief in a lawsuit against the agency itself in 1986. The lawsuit in the U.S. Court of Appeals for the District of Columbia was initiated by the Natural Resources Defense Council. It charged that the agency had ignored scientific evidence of adverse health effects when it set the recommended maximum contaminant level (RMCL) for fluoride in drinking water at 4 ppm.

The EPA union, authorized by law to represent 1100 Washington area scientists, lawyers, and engineers, tried to join in the suit because its members believed that the support documents for the RMCL were unprofessional and an embarrassment to the agency. They charged that the fluoride health effects document, which was written by an outside contractor, had been skewed to meet the political goals of requiring very few communities to remove fluoride from their drinking water and avoiding the suggestion that levels of fluoride found in the drinking water of some communities (between 2 and 4 ppm) might cause adverse health effects.

The union's brief cited many studies showing health effects at 4 ppm that had been omitted from the document. In particular, it opposed EPA's labeling moderate to severe dental fluorosis a mere cosmetic effect that therefore did not need to be protected against by the new standard. It also pointed out that some individuals living in areas with 4 ppm natural fluoride in their drinking water would be at risk of developing crippling skeletal fluorosis. Without comment, the court refused to accept the amicus brief from the EPA union.

In 1984, the South Carolina Department of Health & Environmental Control filed suit against EPA to raise or eliminate the fluoride standard. South Carolina objected to the 4-ppm standard because it did not want any community to have to spend the considerable amount of money—as much as $10 per month per household—required to remove fluoride from its drinking water.

Both suits were thrown out of court in February 1987 by a unanimous decision of the three judges, Ruth B. Ginsburg, Robert Bork, and James Buckley. They determined that "EPA reasonably interpreted the statute, responsibly evaluated the sometimes conflicting evidence in an extensive record," and "provided rational explanations for its determination. We therefore uphold EPA's rule as within the bounds of the agency's permissible discretion."

Jaqueline M. Warren, senior staff attorney at the Natural Resources Defense Council, believes the court made the wrong decision. "I don't think EPA should be allowed to set less protective standards in the absence of significant new evidence that would justify that," she says.

Voices of opposition have been suppressed since early days of fluoridation

Ever since the Public Health Service (PHS) endorsed fluoridation in 1950, detractors have charged that PHS and the medical and dental establishment, such as the American Medical Association (AMA) and the American Dental Association (ADA), have suppressed adverse scientific information about its effects.

Some of those who generally support fluoridation make similar charges. For example, Zev Remba, the Washington Bureau editor of *AGD Impact*, the monthly publication of the Academy of General Dentistry, wrote last year that supporters of fluoridation have had an "unwillingness to release any information that would cast fluorides in a negative light," and that organized dentistry has lost "its objectivity—the ability to consider varying viewpoints together with scientific data to reach a sensible conclusion."

The dozen or so scientists C&EN was able to contact who have done research suggesting negative effects from fluoridation agree on this aspect. They all say that fluoridation research is unusual in this respect.

If the lifeblood of science is open debate of evidence, scientific journals are the veins and arteries of the body scientific. Yet journal editors often have refused for political reasons to publish information that raises questions about fluoridation. A letter from Bernard P. Tillis, editor of the *New York State Dental Journal*, written in February 1984 to Geoffrey E. Smith, a dental surgeon from Melbourne, Australia, says: "Your paper . . . was read here with interest," but it is not appropriate for publication at this time because "the opposition to fluoridation has become virulent again." The paper poses the question: Are people ingesting increasing amounts of fluoride and can they do so with impunity?

Sohan L. Manocha, now a lawyer, and Harold Warner, professor emeritus of biomedical engineering at Emory University medical school in Atlanta, received a similar letter in 1974 from the editor of AMA's *Archives of Environmental Health*. The editor rejected a report Manocha and Warner submitted on enzyme changes in monkeys who were drinking fluoridated water because of reviewers' comments such as: "I would recommend that this paper not be accepted for publication at this time" because "this is a sensitive subject and any publication in this area is subject to interpretation by antifluoridation groups."

These papers were subsequently published in prestigious British journals, *Science Progress* (*Oxford*) and *Histochemical Journal*. Many other authors have reported similar difficulties publishing original data that suggest adverse effects of fluoridated water.

Most authoritative scientific overviews of fluoridation have omitted negative information about it, even when the oversight is pointed out. Phillipe Grandjean, professor of environmental medicine at Odense University in Denmark, wrote to the Environmental Protection Agency in June 1985 about a World Health Organization study on fluorine and fluorides: "Information which could cast any doubt on the advantage of fluoride supplements was left out by the Task Group. Unless I had been present myself, I would have found it hard to believe."

In his 1973 Ph.D. thesis on the fluoridation controversy, Edward Groth III, a Stanford biology graduate student at that time, concluded that the vast majority of reviews of the literature were designed to promote fluoridation, not to examine evidence objectively. Groth also noted a number of antifluoridation reviews that were equally biased.

According to Robert J. Carton, an environmental scientist at EPA, the scientific assessment of fluoride's health risks written by the agency in 1985 "omits 90% of the literature on mutagenicity, most of which suggests fluoride is a mutagen."

Several scientists in the U.S. and other countries who have done research or written reports questioning the benefits of fluoridation or suggesting possible health risks were discouraged by their employers from publishing their findings. After their paper had been rejected by the editor of *Archives of Environmental Health*, Manocha and Warner were told by the director of their department not to try to publish their findings in any other U.S. journal. NIDR had warned the director that the research results would harm the cause of fluoridation. Eventually, Manocha and Warner were granted permission to publish their work in a foreign journal.

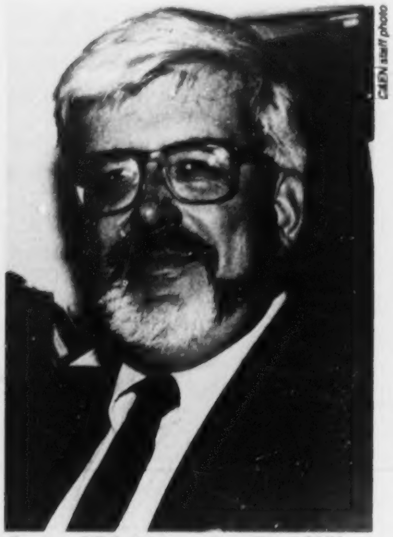
In 1982, John A. Colquhoun, former principal dental officer in the Department of Health in Auckland, New Zealand, was told after writing a report that showed no benefit from fluoridation in New Zealand that the department refused him permission to publish it.

In 1980, Brian Dementi, then toxicologist at the Virginia Department of Health, wrote a comprehensive report on "Fluoride and Drinking Water" that suggested possible health risks from fluoridation. This 36-page study has been purged from the department's library even though it is the only one the department has prepared on the subject. According to current employees, no copy exists anywhere in the department. Spokesmen say the report was thrown

aggravating conditions were present, such as diabetes or impaired kidney function.

In setting the recommended maximum contaminant level for fluoride in drinking water in 1986, EPA considered only crippling skeletal fluorosis as a health effect and established little or no margin of safety, even for this disease. (A margin of safety is a difference between the maximum contaminant level and the level at which health effects first occur in the most susceptible individuals.) According to a Department of Agriculture survey, about 3% of the U.S. population drinks 4 L or more of water per day. Therefore, about 3% of the people who live in areas where the water contains the natural fluoride level of 4 ppm allowed by EPA—such as certain communities in Texas or South Carolina—are ingesting at least 16 mg of fluoride a day, not including the fluoride they derive from other sources, such as toothpaste, food, or air.

Also, because a more or less constant percent of intake is accumulated in bone, persons who consume 8 mg a day for 50 years accumulate about the same



C&EN staff photo

Carton: EPA document omitted 90% of mutagenicity studies

away because it was old but also say the department will be preparing another report on the subject soon.

An ADA white paper written in 1979 states: "Dentists' nonparticipation [in fluoridation promotion] is overt neglect of professional responsibility." An ADA spokesperson says this is still the association's official policy. In recent years, several dentists who have testified on the antifluoridation side have been reprimanded by their state dental officers.

ADA and PHS also have actively discouraged research into the health risks of fluoridation by attacking the work or the character of the investigators. As part of their political campaign, they have over the years collected information on perceived antifluoridation scientists, leaders, and organizations. Newspaper articles about them are stored in files, as are letters about them from various proponents of fluoridation. Little or no effort has been made to verify the accuracy of this information. It is used not only in efforts to counteract arguments of the antifluoridationists, but also to discredit the work and objectivity of U.S. scientists whose research suggests possible health risks from fluoridation.

One example is the false information about the late George L. Waldbott, founder and chief of allergy clinics in four Detroit hospitals, that ADA disseminated widely to discredit the validity of his research. Rather than deal scientifically with his work, ADA mounted a campaign of criticism based largely on a letter from a West German health officer, Heinrich Hornung. The letter made a number of untrue statements, including an allegation that Waldbott obtained his information on patients' reactions to fluoride solely from the use of questionnaires. ADA published Hornung's letter in its journal in 1956 and distributed a news release based on the letter. ADA later published Waldbott's response to this letter. But the widely disseminated original news release was not altered or corrected, and continued to be published in many places. As late as 1985, it was still being quoted. Once political attacks effectively portrayed him as "antifluoridation," Waldbott's work was largely ignored by physicians and scientists.

In November 1962 and 1965, ADA included in its journal long directories of information about antifluoridation scientists, organizations, leaders, and others known to be opposed to fluoridation. Listed in alphabetical order were reputable scientists, convicted felons, food faddists, scientific organizations, and the Ku Klux Klan. Information was given about each, including quotes from newspaper articles, some of which contained false data. The information was published for use by proponents of fluoridation in local fluoridation referenda.

John S. Small, information specialist at the National Institute of Dental Research, is quite willing to talk about the files he keeps on antifluoridation organizations and their leaders. "Of course, we gather information," he says. "These people are running all over the country opposing fluoridation. We have to know what they are up to." Consumer advocate Ralph Nader has a different view of this activity. He calls it an "institutionalized witch-hunt."

It is easy to understand why research on risks of fluoridation has never been more vigorously pursued. Most of the individuals and agencies involved have been promoting fluoridation publicly for nearly 40 years. Research that suggests possible harm threatens them with a loss of face. For example, PHS has historically been the principal source of funds for fluoride research; but ever since June 1950, PHS has been officially committed to and responsible for promoting fluoridation. Thus, the agency has a fundamental conflict of interest.

Colquhoun, now teaching the history of education at the University of Auckland, offers another explanation for what appears to be the suppression of research. He notes that the editorial policy of scientific journals has "generally been to not publish material which overtly opposes the fluoridation paradigm." Scientific journals employ a referee system of peer review. But when the overwhelming majority of experts in an area from which the referees are selected are committed to the shared paradigm of fluoridation, Colquhoun notes, the system lends itself to preservation and continuation of the traditional belief that fluoridation is safe and effective. This results in "single-minded promotion, but poor-quality research, and an apparent inability to flexibly reassess in the presence of unexpected new data," he says.

amount of fluoride in their bones as those who consume 20 mg a day for 20 years. Therefore, for people who drink 2 L or more per day of water with 4 ppm fluoride throughout their lives, there appears to be no margin of safety even for crippling fluorosis. In its regulations for most other drinking water contaminants, EPA has included safety factors of 10 to 100 and has calculated intakes in terms of a lifetime—that is, 70 years instead of 20.

Joseph A. Cotruvo, director of the criteria and standards division of EPA's Office of Drinking Water, says the fact that so few people in the U.S. have actually developed crippling skeletal fluorosis indicates that fluoride levels found in U.S. water are safe and that there is therefore an observed margin of safety. But critics of EPA's standard speculate that there probably have been many more cases of fluorosis—even crippling fluorosis—than the few reported in the literature because most doctors in the U.S. have not studied the disease and do not know how to diagnose it.

Those who ingest much less than 20 mg of fluoride per day may still be at risk of developing less severe

Most of the largest U.S. cities have fluoridated drinking water

City	Population (thousands)	Fluoridation status	Date instituted
New York City	7263	Artificial	1965
Los Angeles	3259	None	
Chicago	3010	Artificial	1956
Houston	1729	Natural/artificial	1982
Philadelphia	1643	Artificial	1954
Detroit	1086	Artificial	1967
San Diego	1015	Discontinued 1954	1952
Dallas	1004	Artificial	1966
San Antonio	914	None	
Phoenix	894	None	
Baltimore	753	Artificial	1952
San Francisco	749	Artificial	1952
Indianapolis	720	Artificial	1951
San Jose	712	None	
Memphis	653	Artificial	1970
Washington, D.C.	626	Artificial	1952
Jacksonville	610	Natural	
Milwaukee	605	Artificial	1953
Boston	574	Artificial	1978
Columbus	566	Artificial	1973
New Orleans	554	Artificial	1974
Cleveland	536	Artificial	1956
Denver	505	Artificial	1954
El Paso	492	Natural	
Seattle	486	Artificial	1969
Nashville-Davidson	474	Artificial	1953
Oklahoma City	443	Artificial	1954
Kansas City (Mo.)	441	Artificial	1981
Fort Worth	430	Artificial	1965
St. Louis	426	Artificial	1955

Sources: Bureau of the Census, National Institute of Dental Research

stages of skeletal fluorosis, such as preclinical forms or the subcrippling clinical stages. In its final report, the Surgeon General's panel said that radiologic changes have been found in bone when fluoride exposure has been about 5 mg per day. Nearly all of those drinking water containing 4 ppm of fluoride and about 3% of the more than 124 million people whose water contains only 1 ppm would have intakes as high as this. It is not known, however, what fraction of those with low-level radiologic changes would suffer joint pains or other clinically obvious adverse health effects. In his landmark study of skeletal fluorosis in cryolite workers in the 1930s, the Danish scientist Kaj Roholm found that some of those with stage I of clinical skeletal fluorosis suffered joint pains and stiffness.

Although skeletal fluorosis has been studied intensely in other countries for more than 40 years, virtually no research has been done in the U.S. to determine how many people are afflicted with the earlier stages of the disease, particularly the preclinical stages. Because some of the clinical symptoms mimic arthritis, the first two clinical phases of skeletal fluorosis could be easily misdiagnosed. Skeletal fluorosis is not even discussed in most medical texts under the effects of fluoride; indeed, a number of texts say the condition is almost nonexistent in the U.S. Even if a doctor is aware of the disease, the early stages are difficult to diagnose.

The possibility that fluoride might cause skeletal abnormalities in children's bones is of particular concern. In its April 1983 draft report, the Surgeon General's committee wrote that moderate and severe dental fluorosis in children may be accompanied by skeletal changes. Although this statement was omitted from the final report in September 1983, the committee did urge more research into the skeletal effects of fluoride, particularly in children. It wrote: "The effects of various levels of fluoride intake on rapidly developing bone in young children are not well understood. Also, the modifying effects of total intake, length of exposure, other nutritional factors, and debilitating illness are not well understood." Since the committee's report was written, PHS and EPA have undertaken no research in this area.

PHS has conducted several studies that it claims show that fluoride levels found in U.S water supplies have had no clearly adverse effects on bones. But the majority of these studies either included a study population too small to detect rare effects or excluded people who would be most likely to suffer from skeletal fluorosis, such as those with kidney disease.

EPA's approach to subtle, preclinical effects of fluoride on the skeleton differs from its usual approach to other environmental agents. For instance, when EPA assessed the health hazards of lead, it made an extraordinary effort to connect the observable effects of low-level exposure (inhibition of certain blood enzymes) with the known adverse effects of slightly higher exposure (decreased synthesis of hemoglobin, anemia, and possible neurotoxic effects). When it set its standard for lead in air, EPA argued that to prevent more serious effects, it needed to limit the more subtle biochemical changes that lead was provoking in millions of children.

By contrast, EPA's assessment of fluoride in water took an almost opposite tack. By defining the most severe known hazard, crippling skeletal fluorosis, as the only effect it was concerned with preventing, EPA dismissed all degrees of fluoride-induced changes in bones less drastic than crippling fluorosis as not being health concerns.

Because fluoride causes denser bones (osteosclerosis), a number of researchers have compared fluoridated and nonfluoridated areas to see if the incidence and severity of osteoporosis is lower in fluoridated areas. A small number of studies in the past 25 years have reported a lower incidence of hip fractures in areas with fluoridated water, compared with nearby areas with low-fluoride water. For example, a recent report, comparing two towns in Finland, prompted widespread media stories that fluoridation is beneficial to the bones of the elderly, as well as to teeth. But a larger number of well-designed studies have found no evidence of a beneficial effect on osteoporosis. However, some of the profluoridation literature states as a fact that fluoridation will help prevent osteoporosis.

Kidney disease

Two areas are of concern in regard to fluoride and kidneys. First, a fairly substantial body of research indicates that people with kidney dysfunction are at increased risk of developing some degree of skeletal fluorosis. Second, a small and inconclusive amount of research suggests that fluoride may actually cause or aggravate kidney disease.

D. Raja Reddy of the Gandhi Medical College in India claims, for example, that "patients suffering from chronic kidney diseases and those with transplanted kidneys do excrete fluoride, though in small quantities, but they are more vulnerable to osteofluorosis and even neurological complications than others." In its final report, the Surgeon General's 1983 committee notes, "As renal function declines, due either to diseases or with aging, plasma and bone fluoride content both increase."

The National Kidney Foundation in its "Position Paper on Fluoridation—1980" also expresses concern about fluoride retention in kidney patients. It cautions doctors "to monitor the fluoride intake of patients with chronic renal impairment," but stops short of recommending the use of fluoride-free drinking water for all patients with kidney disease. It does recommend, however, that dialysis patients use fluoride-free water for their treatments.

Studies show that children with moderately impaired renal function (such as those who have diabetes insipidus), are at some risk of skeletal changes from consumption of fluoridated water, even if the fluoride level is no higher than 1 ppm. A number of researchers have found high concentrations of fluoride in the bones of patients who suffer from kidney disease and have found symptoms of skeletal fluorosis in some of these patients. However, there has been no systematic survey of people with impaired kidney function to determine how many actually suffer a degree of skeletal fluorosis that is clearly detrimental to their health.

Several animal studies suggest that fluoride may have direct adverse effects on the kidneys. For instance, cytological and enzyme changes have been found in the kidneys of squirrel monkeys drinking water with 5 ppm fluoride. It is not known how the changes affect kidney function in monkeys, nor is it known whether humans would suffer similar changes from relatively low levels of fluoride in drinking water. Impaired renal function, however, has been reported to be more common in areas of endemic skeletal fluorosis.

Hypersensitivity

Just as a few people react idiosyncratically to almost anything, some people may have adverse reactions to fluoride whether contained in pills or water. Some individuals seem to be hypersensitive to fluoride pills or drops containing 1 mg or less as well as to fluoride toothpaste. The 1983 edition of the "Physicians Desk Reference" states: "In hypersensitive individuals, fluorides occasionally cause skin eruptions, such as atopic dermatitis, eczema, or urticaria. Gastric distress, headache, and weakness have also been reported. These hypersensitivity reactions usually disappear promptly after discontinuation of the fluoride." (This information was omitted from later editions of the reference.)

Chemicals used to fluoridate water are by-products of fertilizer production

	Consumption for fluoridation, tons per year	Size of community served	How made
Hydrofluosilicic acid	80,000	All sizes	By-product of phosphate fertilizer manufacture
Sodium silicofluoride	60,000	Medium and large	Neutralizing hydrofluosilicic acid with sodium carbonate
Sodium fluoride	3,000	Small	Neutralizing hydrofluosilicic acid with sodium hydroxide

Many of those who agree that some people are hypersensitive to fluoride pills, drops, or mouth rinses deny that anyone could be hypersensitive to fluoridated water, even though just as much or more fluoride is contained in an average person's daily intake of such water (the average water intake of 1 to 2 L has 1 to 2 mg of fluoride) as is contained in the standard pills (0.5 to 1 mg).

Some doctors call such hypersensitive reactions allergies. The American Academy of Allergy, however, defines allergies very narrowly—"quantitatively abnormal responses mediated by specific immunologic mechanisms, and therefore by specific antibodies or by certain sensitized cells (lymphocytes)." According to this definition, the academy says, allergies to fluorides do not exist.

Hans Moolenburgh, a Dutch physician who has studied hypersensitive reactions to fluoride, believes the reactions can be explained as effects of a toxic agent rather than as allergies. In large doses, everyone reacts to fluoride. A small fraction of the population, he says, reacts to much lower levels of fluoride.

The late George L. Waldbott, founder and chief of allergy clinics in four Detroit hospitals and noted antifluoridation activist and author, reported treating at least 500 patients who he concluded reacted negatively to fluoridated water. The symptoms included muscular weakness, chronic fatigue, excessive thirst, headaches, skin rashes, joint pains, digestive upsets, tingling in the extremities, and loss of mental acuity. Waldbott used double-blind tests to determine whether fluoride was the cause of symptoms in many of his cases. In each of these patients, the symptoms disappeared when the fluoride was taken away without the patient's knowledge and reappeared when it was given again, but not with the administration of other possible agents.

Other investigators have reported similar cases. Reuben Feltman and George Kosel, then researchers at Passaic General Hospital in New Jersey, found that 1% of their subjects, who were children and pregnant women, reacted adversely to daily pills containing 1.0 to 1.2 mg of fluoride. The reactions, which affected the skin and gastrointestinal and nervous systems, disappeared when the fluoride was discontinued without the patients' knowledge.

Moolenburgh, G. W. Grimbergen, and a number of other Dutch doctors performed double-blind experiments on patients who became ill after fluoridation began in the Netherlands. By using coded bottles of drinking water, some fluoridated and some not, the physicians showed that the symptoms were caused by fluoride, rather than some other factor.

Moreover, a report by the British Royal College of Physicians states that some patients receiving 9 mg of fluoride per day for osteoporosis suffered adverse side effects. This is about the same intake some would have in areas where the water fluoride level is 2 ppm.

Because the number of studies has been small, it is not known with certainty what fraction of the population may be hypersensitive to fluoride. Since all of the reported symptoms can be caused by other factors, reactions to fluoride could go undiagnosed unless a physician was looking specifically for fluoride sensitivity.

Enzyme and mutagenic effects

Sodium fluoride is used in many in-vitro studies to block the action of enzymes, in part because it can interfere with so many different enzymes.

One way the fluoride ion serves as an enzyme inhibitor in the lab is by acting on the GTP-binding proteins (or G-proteins). Fluoride ion also may disrupt enzymes by forming strong hydrogen bonds with amides. Fluoride switches off an enzyme by attacking its weakest links—the delicately balanced network of hydrogen bonds surrounding the active site. In some enzymes, the fluoride ion attaches itself to the atom at the heart of the enzyme and then disrupts the active site by attracting groups that can form strong hydrogen bonds to itself. Eventually, this inactivates the enzyme by changing its molecular conformation.

Because enzymes mediate most of the biochemical processes essential to life, any environmental agent that can affect a wide range of enzymes could, at least in theory, have a wide variety of effects on an organism's health. For that reason alone, potential effects of fluoride on enzymes are of great interest. In addition, as has been discussed earlier, effects on enzymes are often the first detectable biological changes produced in an organism exposed to a toxic agent, just as enzyme changes in the heme biosynthetic pathway precede the onset of lead-induced anemia. Detailed knowledge of fluoride's effects on a number of human enzymes could lead to an array of sensitive tests for the earliest signs of possible harm from excessive intake of this element and more precise identification of individuals who are at risk.

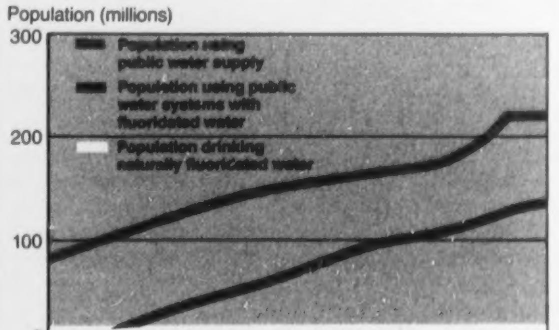
Studies on enzyme preparations in test tubes, however, don't necessarily predict what will happen in living humans. In at least 11 in-vivo animal studies, fluoride has been shown to influence enzyme activity. In some tests, enzyme activity was depressed; in others, it was stimulated. In addition, one study indicates a transient decrease in human serum enzyme activity associated with the advent of water fluoridation. But there have been few other studies to measure the effects of typical levels of fluoride intake on enzyme activity in people.

Some scientists believe that interference with enzyme activity is the major mechanism by which fluoride exerts physiological effects. Certain changes in enzyme activity can be minor, easily repaired by the body. But others could be the first signs of more serious alterations that would take place with continued exposure to fluoride.

Just as the fluoride ion may disrupt enzymes with its ability to form strong hydrogen bonds, it may also disrupt DNA by interfering with its hydrogen bonding. The evidence for this mechanism consists of theoretical calculations, however, and some scientists, such as George R. Martin, chief of the laboratory of developmental biology and anomalies at NIDR, do not find it at all convincing.

A great many lab tests have been performed to measure the possible mutagenicity of the fluoride ion. The results are contradictory and often very confusing. Some of the positive mutagenicity tests involve very high concentrations of fluoride ion, so high that they would not be found anywhere in the human body. Others involve levels comparable to those in drinking water. However, the important consideration is not fluoride levels found in drinking water, but levels found in the human body. Geoffrey E. Smith, dental surgeon from Melbourne, Australia, says that when bones lose fluoride, localized high concentrations may result.

For example, in 1982, Aly H. Mohamed and Mary E. Chandler of the University of Missouri in Kansas City reported that 1 to 200 ppm fluoride in drinking water induced changes in a dose-dependent manner in bone



Population drinking artificially fluoridated water has grown steadily since 1950

Source: National Institute of Dental Research

David B. Scott, who later became head of NIDR, examines child during early years of fluoridation in Grand Rapids, Mich.

marrow cell chromosomes and spermatocytes of living mice. In 1978, Danuta Jachimczak of the Pomeranian Medical Academy in Szezecin, Poland, showed that fluoride levels as low as 1 ppm caused changes in the chromosomes of human leucocytes in vitro.

Even if all the mutagenicity tests were positive, this would not prove fluoride is a mutagen in humans. But scientists consider a chemical a more likely mutagen if several types of lab tests are positive.

John R. Bucher of the National Institute of Environmental Health Sciences says that tests in his lab show sodium fluoride mutagenic for cultured lymphoma cells derived from mice. He notes that a number of similar studies have been published by other investigators. Because most carcinogens are also mutagens, evidence of mutagenicity also bears on the issue of fluoride's potential for carcinogenicity. Bucher's results do not prove sodium fluoride is a carcinogen, but do "point out the need to test the chemical in the two-year rodent bioassay, which we are doing," he explains.

Because he believes that epidemiological studies show that fluoride has no effect on birth defects and cancer, Martin says he is not concerned about the positive mutagenicity studies. John S. Small, information specialist at NIDR who has a similar view of the epidemiology studies, calls the mutagenicity question a "used-up issue."

Very little work has been done on fluoride's potential mutagenicity in humans. In one study involving only six patients receiving fluoride treatment for osteoporosis, inhibition of DNA repair was observed in one patient. But no firm conclusions can be drawn from such limited research, and more intensive research simply has not been pursued.

Birth defects

If the fluoride ion is a mutagen, it may be capable of causing birth defects in humans. Few studies have been done in this area. During the 1950s, Ionel Rapaport, a researcher at the Psychiatric Institute of the University of Wisconsin who specialized in the epidemiology of mental disorders, found that babies born in areas of North Dakota, South Dakota, Illinois, and Wisconsin with natural fluoride in drinking water had twice the incidence of Down's syndrome as those born in fluoride-free areas. However, a few more recent surveys have shown a smaller or no relation between water fluoridation and Down's syndrome.

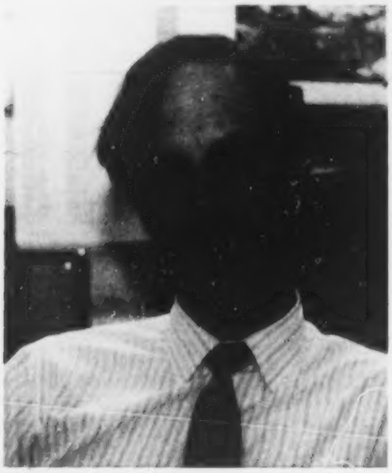
In 1976, J. David Erickson, an epidemiologist at the Centers for Disease Control, looked at the rates of overall birth defects in the fluoridated and unfluoridated counties around Atlanta and also at national birth defect data supplied by the National Cleft Lip & Palate Intelligence Service (NCLPIS). Like Rapaport, he recorded a higher rate of Down's syndrome births among younger mothers in the fluoridated areas around Atlanta, but he found no substantial overall differences in the birth defect rates that form a consistent pattern for the metropolitan Atlanta and the NCLPIS data. However, many of the mothers in the Atlanta area counties had been exposed to fluoridation for only a few years and the NCLPIS data indicated substantial underreporting of birth defects. Clearly, there is need for more work in this area.

Cancer

Two types of research have been done to determine if fluoride causes cancer—lab studies of animals and human epidemiology studies. Neither kind of research has shown clearly that fluoride is a carcinogen in animals or humans. But the studies have not been extensive enough to show that it clearly is not a carcinogen.

A few animal bioassays on fluoride in the 1950s produced contradictory and inconclusive evidence on the ion's potential to cause or accelerate cancer. In 1977, Congress requested that the National Institutes of Health conduct large-scale animal tests of fluoride for carcinogenicity. In the first chronic test, certain rats in both the control and dosed groups became ill and died at an early age, probably because their feed, highly purified to remove fluoride, was deficient in certain essential trace elements. The study on 360 mice and rats was done over again with a different feed. Results are scheduled to be available in 1990. Because of its well-established effects on many enzymes in vitro, Groth suggests that fluoride also should probably be tested for cocarcinogenicity (ability to act as a promoter of cancer) in animals. But no such research is now under way.

Reprints of this C&EN special report will be available in black and white at $5.00 per copy. For 10 or more copies, $3.00 per copy. Send requests to: Distribution, Room 210, American Chemical Society, 1155—16th St., N.W., Washington, D.C. 20036. On orders of $20 or less, please send check or money order with request.



C&EN staff photo

Groth: science cannot say how much uncertainty we should tolerate

Cancer epidemiology studies are probably the most controversial issue in the fluoride debate. In the 1950s, PHS did some general mortality studies of crude overall death rates from all causes. It found no excess mortality from cancer or other causes in naturally fluoridated areas, compared with areas without fluoride in water.

In 1977, biochemist John Yiamouyiannis, president of the Safe Water Foundation (a citizens group opposed to fluoridation), and Dean Burk, retired after working for 35 years as a biochemist at the National Cancer Institute, published a study comparing cancer mortality rates from the 10 largest U.S. cities with fluoridated water with mortality rates from 10 of the largest cities with nonfluoridated water. Before 1952, when fluoridation had not yet begun in most of these cities, the cancer death rates rose together. After 1952, the death rates for people over 45 in the cities with nonfluoridated water were 4 to 5% lower than those for the cities with fluoridated water. In England, Sir Richard Doll and Leo Kinlen of Oxford University and Peter D. Oldham and D. John Newell of the Royal Statistical Society at about the same time completed studies that show no excess of cancer mortality in those same cities in the U.S. with fluoridated water.

The National Research Council (NRC) reviewed this discrepancy in 1977 and concluded that the conflicting results could be explained in large part by the different data sets and different analytical approaches used by the investigators. According to the NRC analysis, the margin of possible error in the most sensitive cancer study is about three cancer deaths per 100,000 people or 4000 possible excess or fewer cancer deaths per year among the 130 million individuals drinking fluoridated water in the U.S.

A June article in the *Proceedings of the Pennsylvania Academy of Science* by attorney John R. Graham, Burk, and Pierre J. Morin, former scientific adviser for the minister of environment in Quebec, also reviews this controversy. It concludes that, compared with the unfluoridated cities, there is an excess of 20 to 30 cancer deaths per 100,000 people who live in the major fluoridated cities of the U.S. for at least 15 to 20 years.

Several investigators have looked for a more specific relationship between stomach cancer and fluoridation. The hypothesis is that fluoride would be more likely to cause stomach cancer than any other type because fluoride in the stomach forms hydrofluoric acid, a powerful irritant that is mutagenic in several in-vitro lab tests. In 1978, CDC's Erickson, after correcting for age, race, and sex, found the death rate from cancer of the digestive system was 9% higher in cities with fluoridated water. However, when he subtracted all subjects with Asian and Hispanic surnames and corrected for education and population density, the excess disappeared.

The Knox report, a comprehensive review of most fluoride cancer studies that was completed in 1985 by the Royal College of Physicians in England, concludes that there is no convincing evidence that cancer death rates are higher in areas with fluoridated water. Thus, as with most environmental agents that have been studied for their effects on cancer, the results for fluoride are still inconclusive.

Values influence the choice

Even if all evidence from fluoride research indicated that the risks are slight, not everyone would agree that it is proper to fluoridate water supplies. Obviously, there is never enough time or money to investigate all the scientific questions, and some research results will always be equivocal. And, at least in environmental health, it is, of course, impossible for science to establish anything with absolute certainty.

The decision to fluoridate a community's water or not boils down to a matter of values. Scientific evidence can make the choice more clearcut, more rational, but the choice can't be made purely on the basis of scientific evidence. So long as there is uncertainty about risk from fluoridation, some people will not want to accept that risk. And others who favor fluoridation will demand proof of harm beyond a reasonable doubt before they reject it. According to Groth, "A scientific assessment cannot say what degree of adverse effects is acceptable in return for the expected benefits. ... It cannot say how much uncertainty we should tolerate in estimates of hazards when more than 100 million people are exposed to lifelong ingestion of fluoridated water. Those decisions are value judgments, and scientists' values are no better than everyone else's."

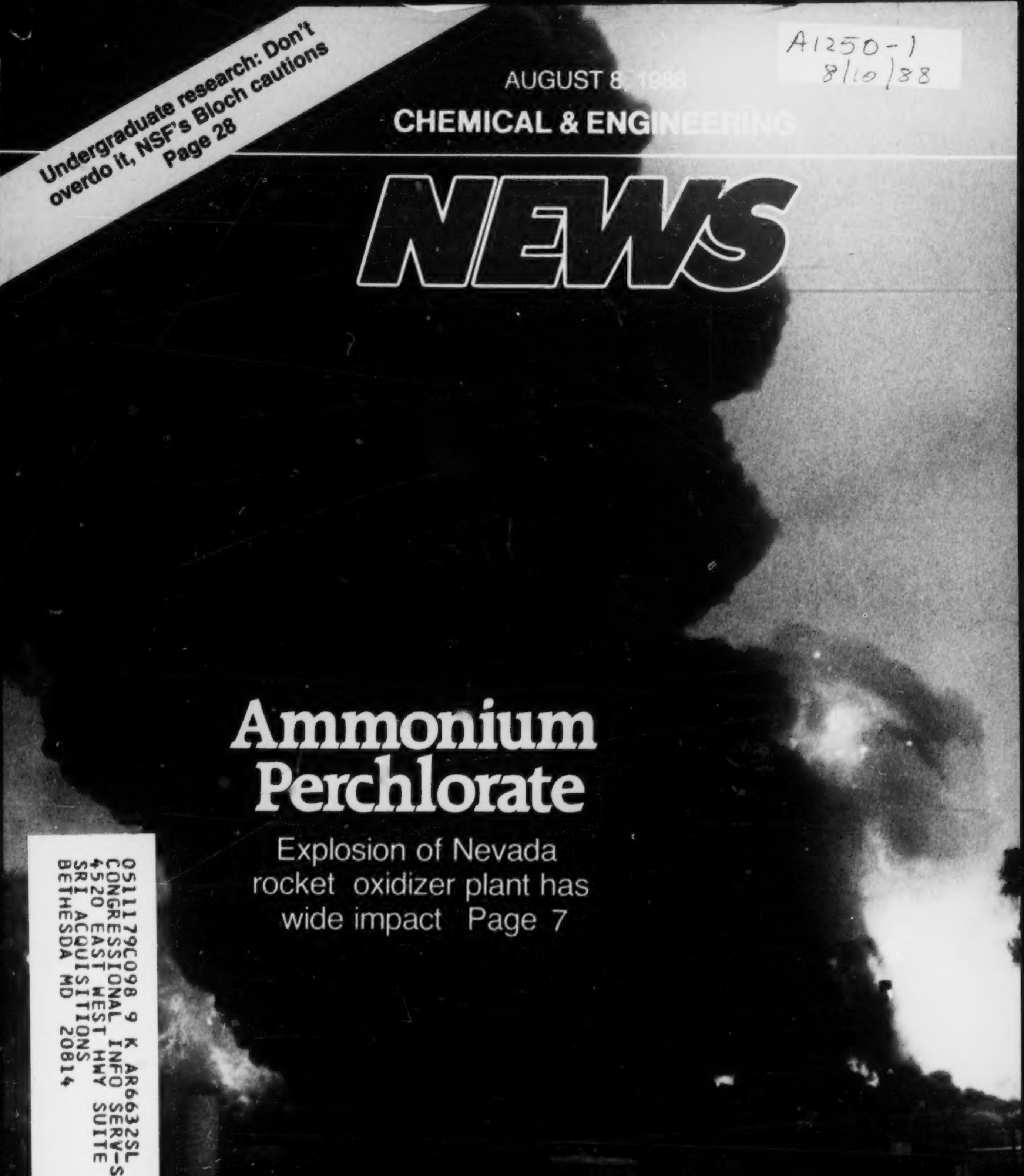
If the risks could be shown to be minuscule beyond a reasonable doubt, it still might make no sense to fluoridate water supplies if the benefits are also small. Perhaps the best approach is, as Groth suggests, not to make the issue whether to fluoridate public water supplies or not. Such an approach allows for no compromise: A water supply is either fluoridated or it is not. Perhaps a better question for policy makers, scientists, and citizens to address is: "What is the best way to promote dental health?" he says. Fluoridation might well be part of the answer, Groth suggests, but communities should simultaneously examine the pros and cons of a variety of other approaches, too. That way, the characteristic all-or-nothing, fight-to-the-finish political battle over fluoridation might some day truly become a historical curiosity. □

A1250-1
8/10/88

Undergraduate research: Don't overdo it, NSF's Bloch cautions
Page 28

AUGUST 8, 1988

CHEMICAL & ENGINEERING NEWS



Ammonium Perchlorate

Explosion of Nevada rocket oxidizer plant has wide impact Page 7

0511179C098 9 K AR6632SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 32
CENEAR 66 (32) 1–56
ISSN 0009-2347

AUGUST 8, 1988

News of the Week

- **Natural Resources Defense Council asserts EPA's final rules on cutting production of CFCs will not protect the stratospheric ozone layer, as required by law. Page 4**
- **Purchase of Koppers Chemical by its own management and Gordon Cain has been canceled because of potential environmental liabilities. Page 5**
- **Iraq continues to use chemical weapons as U.S. attempts to move negotiations forward for a global treaty on such weapons. Page 5**
- **Congress passes internationally controversial trade bill, which displeases Japan and Europe but boosts U.S. labor, industry. Page 6**
- **Two candidates for ACS posts have been nominated by petition. Page 6**

Cover: Third in a series of explosions on May 4 that destroyed ammonium perchlorate plant in Henderson, Nev., owned by Pacific Engineering & Production Co. of Nevada. Photo by Arthur C. Strandberg

Letters 2

Concentrates
Business 16
Government 21
Science/Technology 25

The Departments
ACS Comment 31
ACS News 32
Meetings 38
People 44
Newscripts 56

Business

Günter Metz, the new president of the European Council of Chemical Manufacturers' Federations, discusses free-trade plans for Europe in 1992, other important issues. **Page 18**

Caustic soda prices are increasing because of the unique coproduct relationship of chlorine and caustic soda and the current high demand for caustic soda. **Page 20**

Government

The 1988 Democratic Party platform is succinct and short on specifics, with little mention of issues facing the research community. **Page 22**

Lower lead levels in drinking water is the subject of a new standard that EPA is working on and of a bill before the House. **Page23**

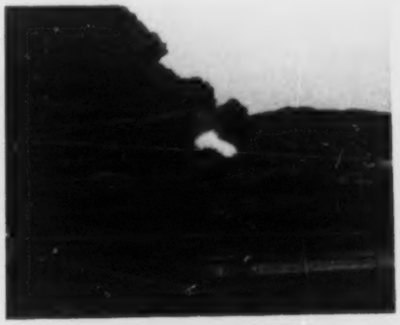
Science

Porphyrin analog with five coordinating nitrogen atoms may serve as springboard for variety of applications. **Page 26**

Microscopic electric motor has 60-μm diameter silicon rotor that is driven by electrostatic forces. **Page 26**

Education

Current issues involving student research at four-year colleges were discussed at a recent conference at Carleton College. **Page 28**



News Focus

Explosion at Henderson, Nev., rocket oxidizer plant in May has raised concerns about supply of ammonium perchlorate and caused widespread fear among residents of Henderson, where second oxidizer plant still operates. Page 7

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production / Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

CHEMICAL SAFETY

Toluene and sulfur dichloride

SIR: This letter is to alert interested parties to an exothermic reaction between toluene and sulfur dichloride. This reaction is accelerated greatly in the presence of iron or ferric chloride.

Recently, a serious incident, including a vessel rupture from overpressurization, occurred at one of our facilities when toluene was added to a carbon steel head tank containing sulfur dichloride.

Subsequent hazards laboratory testing revealed that an exothermic reaction occurring between toluene and sulfur dichloride is catalyzed by iron or ferric chloride.

We have concluded that the pressure generated by this catalytic reaction caused the head tank rupture, fatally injuring one employee. References to this catalytic reaction were not found by extensive searches of the literature.

Joseph C. Caporossi
Manager, Safety, Health, and Emergency Response
American Cyanamid Co.
Wayne, N.J.

Editor's note: According to Occidental Chemical Corp.'s material safety data sheet, conditions contributing to the instability of sulfur dichloride include heat, exposure to moisture, and contact with alkalies or organic matter. Keep lights, flames, or sparks away from the drum or tank opening, since flammable hydrogen gas may be formed upon the reaction of sulfur dichloride with steel in the presence of moisture. Sulfur dichloride reacts vigorously with strong alkalies, water, and other alkaline chemicals. Hydrolysis of sulfur dichloride in the presence of water can release hydrogen chloride, sulfur dioxide, and hydrogen sulfide.

2-Indanecarboxaldehyde

SIR: We recently had occasion to prepare a small quantity of 2-indanecarboxaldehyde from 2-indanone via the well-precedented Wittig reaction with methoxymethylenetriphenylphosphorane followed by acidic hydrolysis of the intermediate enol ether. The reaction proceeded normally until attempted bulb-to-bulb distillation of the crude product (about 2 g) using a Kugelrohr apparatus. At 70 °C and 0.1 torr, just as the product was beginning to distill, a violent detonation occurred, which pulverized the glass flask and totally destroyed the distillation apparatus. Fortunately, the apparatus was in a good hood and the student carrying out the procedure was not adjacent to the incident. Had he been looking into the Kugelrohr at the time of the explosion, serious injury would very likely have resulted despite the use of safety goggles.

Since the reaction sequence employed for this transformation is widely employed, we must assume that the compound itself is thermally unstable either in its own right or as a result of contamination by reaction by-products. No residue was available for analysis.

It is known that cycloalkyl carboxaldehydes decompose with time and are generally difficult to purify, but we have successfully distilled both cyclohexane- and cyclopentanecarboxaldehyde on numerous occasions with no incident. Since we have been unable to rationalize this incident in terms of the causative factors, we are discontinuing the distillation of 2-indanecarboxaldehyde and recommend that others do likewise.

T. Howard Black
Associate Professor
Eastern Illinois University

Selenium levels decreasing

SIR: F. Henry Firsching's warning of coal's negative environmental impact (C&EN, June 20, page 3) is well taken in regard to the greenhouse effect. Added to this is the growing evidence that acid rain is a major factor causing reduced plant uptake of the essential element selenium. Finland now requires the addition of selenium to fertilizer, and the Food & Drug Administration has trebled the level of selenium permitted to be added to animal feeds. The various reasons, including acid rain, why the level of selenium in the food chain is decreasing are well documented.

Development of the hypothesis as to why the air to soil to plant to animal

Correction

- July 25, page 2: In Lyell Carver's letter, a typo in paragraph four changed the one-sixth share each of three children would inherit to one-sixteenth.

CFC PRODUCTION CUTS: EPA rules already under attack

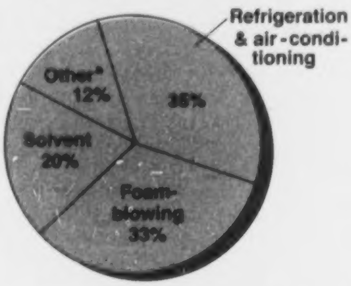
No sooner did the Environmental Protection Agency issue final rules on cutting chlorofluorocarbon (CFC) production last week than it was hit with the threat of a lawsuit by the Natural Resources Defense Council. The national environmental group asserts EPA's regulations will not protect the stratospheric ozone layer, as required by law, or even keep the current depletion problem from getting worse.

The new EPA regulations echo the terms of the Montreal Protocol on Substances That Deplete the Ozone Layer, the international agreement to control the output of both CFCs and halons (fluorocarbons that contain bromine atoms). Production of CFCs is to be frozen at 1986 levels on July 1, 1989. CFC output is to be cut 20% by mid-1993, then an additional 30% by mid-1998. Halon output is to be frozen at 1986 levels on July 1, 1989.

For the Montreal Protocol to go into effect on schedule, it must be ratified by at least 11 countries accounting for two thirds of world consumption. Six countries (Mexico, the U.S., Canada, Norway, Sweden, and New Zealand) already have done so. Japan and the European Community are expected to ratify the pact shortly, putting the count over the top. The new EPA rules will go into force when the protocol does.

"These regulations are a helpful start, but the reductions are too little and too slow to protect the public health and the ozone layer," says NRDC senior project attorney David A. Wirth. Because fully halogenated CFCs have such long atmospheric lifetimes, the chlorine content of the atmosphere will continue to increase for many years despite the scheduled production cuts.

Cooling, foam-blowing are largest U.S. CFC uses



1986 total consumption = 670 million lb

a Includes aerosols, sterilization, food freezing, and other miscellaneous uses.
Source: Environmental Protection Agency

"EPA's own calculations say an 85% intermediate reduction is needed to keep the atmospheric concentration of chlorine from increasing," Wirth points out. Scientists studying the ozone problem have repeatedly stated that even at today's concentrations, chlorine-catalyzed reactions are causing massive losses of ozone over Antarctica and have been implicated in smaller decreases in ozone throughout the rest of the globe (C&EN, March 21, page 6). Thus, Wirth argues, the U.S. should unilaterally impose sharper reductions in CFC use.

EPA has considered and rejected the strategy of acting alone, preferring to work toward a stronger international agreement, says Eileen Claussen, the agency's acting deputy assistant administrator for air and radiation. "We would like to push other nations so that we end up with a protocol that goes to a 95% cut," she says. "In the end we'll be more successful if we move with the rest of the world." EPA plans to be a forceful presence at an international meeting set for October in the Netherlands at which the nations that have signed the Montreal Protocol will consider whether it needs to be strengthened, she says.

Meanwhile, EPA is considering whether to modify the way in which it has decided to control halocarbon output. The agency has given the seven firms that make halocarbons in the U.S. rights to produce them in the future. The quotas have been allocated in proportion to each firm's share of the market for 1986. U.S. CFC producers are Du Pont, Allied-Signal, Pennwalt, Kaiser Chemicals, and Racon. Besides Du Pont, Great Lakes Chemical Corp. and ICI Americas make halons.

Now the agency is pondering whether to impose a regulatory fee on the producers in order to recoup windfall profits that might be an unintended result of the quota system. As the supply of CFCs shrinks, prices may increase as much as fivefold, according to EPA. The agency estimates producers could earn an additional $2 billion to $7 billion as prices rise, depending on how fast CFC users switch to other technologies and substitute products.

"We're afraid if the producers are making a lot of money off of the existing CFCs, there won't be an incentive to come up with substitutes," Claussen says.

Du Pont, the world's largest CFC producer, insists no furthur incentives to move to substitutes are necessary, pointing out that it has already pledged to get out of the business entirely. "We expect to be able to complete our phaseout by the year 2000," says Joseph M. Steed, environmental manager for Du Pont's Freon Products Division. "Producers are already stumbling all over each other racing for new alternatives."

Pamela Zurer

Impact Widening from Explosion Of Nevada Rocket Oxidizer Plant

PEPCON starts to rebuild wrecked Henderson unit at distant site, but concern rises over supply of ammonium perchlorate; residents fear danger from Kerr-McGee perchlorate plant still in their midst

Richard J. Seltzer, C&EN Washington

Three months ago, shortly before noon on May 4, the town of Henderson, Nev., was rocked by a series of explosions at a plant owned by Pacific Engineering & Production Co. of Nevada (PEPCON). The impact was immediate and dramatic, and is still widening.

On one level, the disaster created a critical national problem. What went up in smoke and flame in a matter of minutes was an inventory of more than 8 million lb of ammonium perchlorate (AP), and approximately half the U.S. capacity for making this oxidizer used in solid-fueled rockets (C&EN, June 13, page 9). The accident has raised concerns in government and industry about allocation and supply of AP and the impact on national space and missile programs. Plans are in the works for restoring production at PEPCON and for expanding AP capacity at the only other U.S. producer, Kerr-McGee Chemical Corp., also sited in Henderson.

On another level, however, PEPCON, Kerr-McGee, and Henderson furnish an intriguing case study of relations between chemical industry and a community. The series of blasts killed two PEPCON senior executives, injured more than 350 local residents, and caused damage estimated to exceed $73 million (C&EN, July 4, page 5). Lack of federal aid has upset the community, and fear and concern are widespread about the Kerr-McGee plant still operating in Henderson.

The disaster that leveled PEPCON's ammonium perchlorate plant only took about 15 minutes—from the first fire to the last of the explosions. One company worker describes his experience this way:

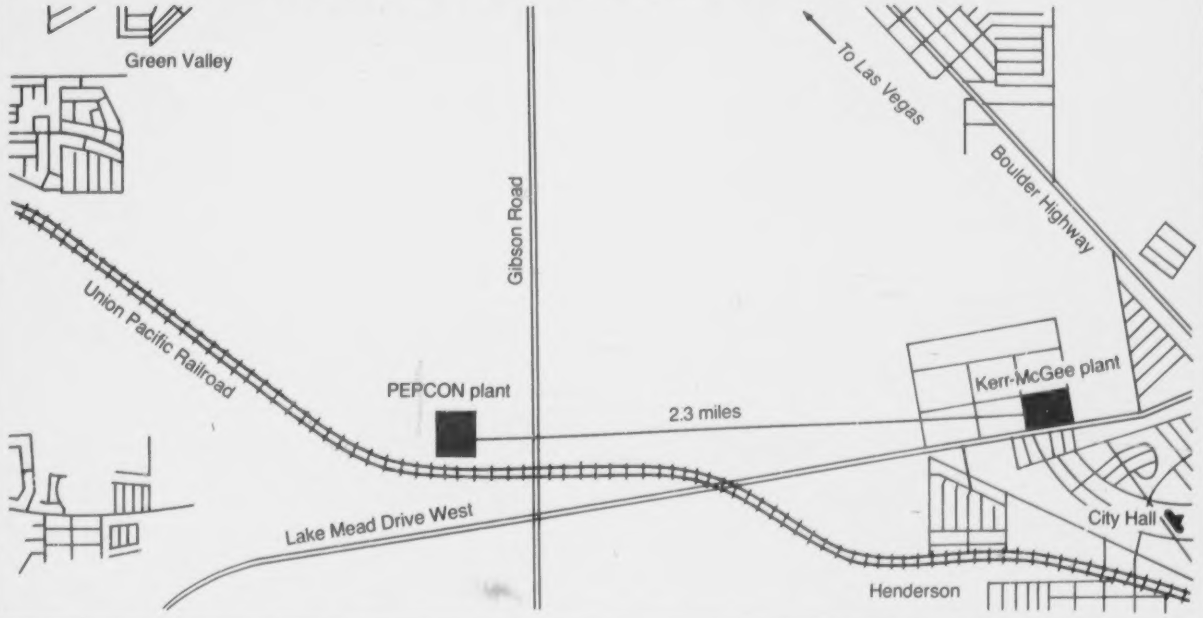
"I was working and I heard a few pops. Then there was a bigger explosion and the ceiling fell down, and I was almost knocked out. I didn't know what was happening, but I heard someone yelling that there was a fire in the plant. Everyone was running out as fast as possible. Flames were shooting 50 to 100 feet into the air. So I ran away from the building.

Photo by Arthur C. Strandberg

Second in series of explosions erupts at 11:58 AM on May 4 at PEPCON'S perchlorate plant in Henderson

"I got to my truck, but the hood was already on fire and I couldn't put it out. Then I felt the hottest heat I've ever felt. The whole lot was full of AP and I saw most of the AP stored was on fire. My face got sunburned, it was so hot. I ran to about 25 yards away from the storage field and there was a second explosion. I was thrown through the air by the shock wave. I was covered with greyish-white smoke, and had a burning sensation and trouble breathing. I got up again and ran some more. There was a constant rain of dark grey grit, probably asphalt from where the AP was stored. I got further away and there was a third explosion, again throwing me. Finally, I got about 350 or 400 yards away and started to walk. That's when

Ammonium perchlorate plants sited near populated areas

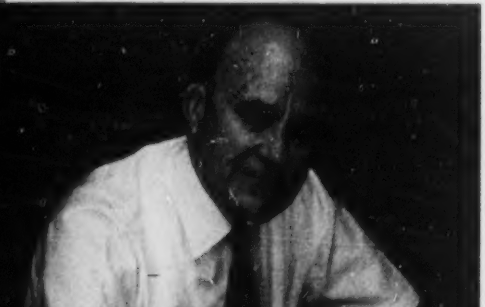


the final explosion came. It was the biggest of all—it was just incredible. The shock wave goes through you like electricity, and the whole ground was shaking."

Left behind in ruins was a plant that had been making 24 million lb a year of the solid fuel oxidizer, with a capacity for up to 40 million lb. It was the principal supplier of AP for the space shuttle's solid rocket boosters. And it was the sole supplier for the largest U.S. unmanned rocket, Titan IV; for the most widely used naval tactical system, the Standard Missile; and for the second stage of the Peacekeeper (MX) missile. PEPCON had 48 plant workers on site, with 60 administrative personnel.

The firm was started in November 1955 by three men, including the father of the current chairman, president, and chief executive officer, Fred D. Gibson Jr. The trio had left their positions as officers, owners, and directors of Western Electrochemical Co. (WECCO), which had built the first AP production facility in the U.S., after WECCO was acquired by American Potash. Gibson Jr. also left WECCO for PEPCON.

PEPCON's successful research on a platinum substitute anode for perchlorate production led it to build an AP pilot plant in 1958 at the current site on Gibson Road in Henderson. The firm expanded to a capacity of 5.5 million lb a year in 1959 and 11 million in 1961.


Gibson: AP production in six months

Green Valley resident Walz (left) and Rep. Roe speak at House subcommittee hearing in Henderson

C&EN staff photos

At that time, three firms made AP besides PEPCON: American Potash, Pennsalt Chemicals (later renamed Pennwalt), and Hooker Chemical. The market was not big enough to support four firms, however, and Pennsalt and Hooker dropped out in the mid-1960s. American Potash was acquired by Kerr-McGee in 1967, leaving PEPCON and Kerr-McGee as the only two producers. Both firms were encouraged to expand with federal aid as the space shuttle program geared up in the early 1980s. PEPCON raised capacity to 40 million lb a year and Kerr-McGee to 36 million.

In 1982, PEPCON merged with and became a subsidiary of American Pacific Corp., a publicly owned corporation (traded over the counter) also headed by Gibson. His brother, James I. Gibson, serves as executive vice president of both PEPCON and American Pacific, and wields considerable influence as a senior member of the Nevada state Senate. The firm carries on two other businesses: pollution control equipment and engineering services, adapting electrochemical technology used in AP production; and development of an industrial/commercial park, Gibson Business Park, in Henderson.

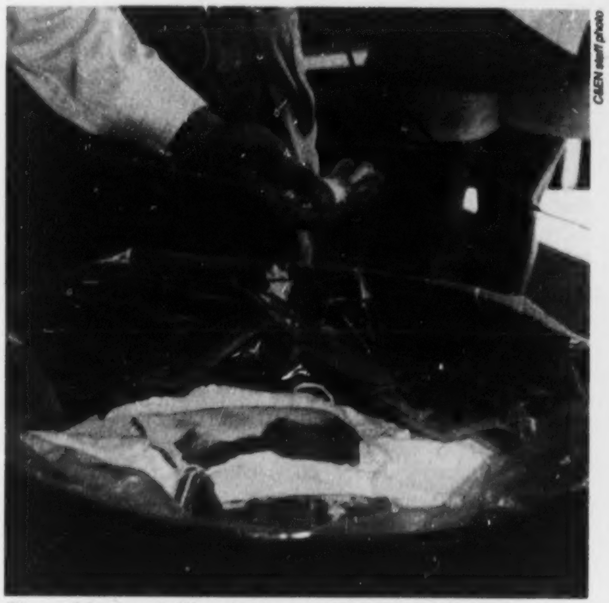
Both AP plants—PEPCON's and the Kerr-McGee unit about 2.3 miles away—were built in the Las Vegas suburb because of two advantages: inexpensive hydropower for the electrolytic processes from nearby Hoover Dam; and a dry desert climate permitting easier handling and storage of the hygroscopic product.

Production of ammonium perchlorate, NH_4ClO_4—a white, crystalline substance—involves relatively simple chemistry. First, sodium chloride is converted to sodium chlorate and then to sodium perchlorate in two electrolysis steps. Next, sodium perchlorate is reacted with ammonium chloride (formed from ammonia and hydrochloric acid) in a double exchange reaction to yield AP and sodium chloride.

However, Gibson tells C&EN, "it's as much an art as a science." The art, generally held proprietary, includes controlling such parameters as particle size distribution, particle shape, purity, and moisture content to achieve desired specifications.

Kerr-McGee uses a continuous process, whereas PEPCON employs a batch process. One advantage of the batch process, says Raymond C. Rhees, PEPCON's vice president for R&D, is that it allows better tailoring of crystallization to produce a desired particle size distribution. This means less blending is required and lower inventories can be kept.

AP is a critical component of a stunning variety of solid fuel rockets used for space programs and for strategic and tactical military uses. For example, AP constitutes about 70% of the solid propellant in space shuttle booster rockets. The pair of booster rockets used for each shuttle launch consumes about 1.7 million lb of AP. The Air Force's workhorse Titan IV unmanned rocket, by contrast, uses less than half as much AP, 800,000 lb per launch. AP has ideal properties for a rocket oxidizer, yielding all gaseous products and possessing a high flame temperature, notes pyrotechnics expert John Conkling of Washington College, Chestertown, Md.



C&EN staff photo

Fine white crystalline AP is stored with dessicant in plastic-lined barrel until crossblended at Kerr-McGee

Figures collected recently by the Defense Department estimate total U.S. demand for AP at 38.8 million lb in 1988, rising to 60.1 million lb in 1989 with expected resumption of shuttle flights and other missions. With only the Kerr-McGee plant now producing, and with a capacity of 36 million lb a year, many observers fear that the U.S. may face a crisis of short supply in its space and missile programs over the next three years.

The problem is not only quantitative, but qualitative. Only PEPCON has passed qualification requirements to supply AP for the Titan IV, Standard Missile, and several other rockets: Product could not be diverted from Kerr-McGee for these rockets without going through qualification tests taking many months.

A recovery strategy—with plans for rebuilding production and setting of priorities for supplies in the meantime—is being formulated by an ad-hoc interagency working group. On it are representatives from the National Security Council (NSC), office of the Secretary of Defense, Air Force, Joint Chiefs of Staff, National Aeronautics & Space Administration, Department of Transportation, Office of Management & Budget, Department of Justice, Federal Emergency Management Agency (FEMA), Department of Energy, Department of Commerce, and Department of State.

This working group has sent recommendations to NSC, and that council has made some decisions on near-term allocations. The good news is that officials believe the supplies on hand in inventory and being produced by Kerr-McGee will be able to cover all AP requirements in 1988, although some schedules may have to be stretched out. The bad news is that a crunch is likely next year and the year after, until PEPCON starts supplying AP from a new plant and Kerr-McGee expands its output.

Morton Thiokol, producer of the shuttle booster rockets for NASA, already has enough AP on hand for a remaining on-ground test firing and for the first four shuttle flights. The explosion at PEPCON destroyed AP already produced and being readied for shipment to Thiokol for the fifth and sixth shuttle launches. Therefore, NSC has given top priority to the fifth shuttle launch. Kerr-McGee is already delivering AP to Thiokol to prepare for that flight, scheduled to carry the Magellan spacecraft during a "launch window" next April to orbit Venus. It will use high-resolution radar to obtain detailed images of the planet's surface through its thick clouds of sulfuric acid and carbon dioxide.

The next AP delivery from Kerr-McGee will go to the Department of Defense (DOD) for a Titan 34D launch. And NSC has formulated a plan to handle the rest of AP demand this year. DOD is finalizing this document and will soon send it to the Commerce Department's Office of Industrial Resources Administration. This office is charged under the Defense Production Act of 1950 with overseeing production and distribution of critical materials to meet defense, space, and other needs.

The big question is what happens in the next couple of years? How long will it take PEPCON to start production and to pass NASA and DOD qualifying tests for use of its AP? When will Kerr-McGee begin expanded production? The working group will meet next month to start considering allocations for the first six months of 1989.

The most optimistic assumption is that PEPCON can resume production and pass qualifying tests by next summer, and that Kerr-McGee will expand its capacity with a new facility by then. If this can be done, says Daniel S. Rak, deputy assistant secretary of the Air Force, who chairs the AP interagency working group, it may be possible to reduce the AP shortfall in 1989 to less than 3 million lb out of a demand of 60 million.

Allocation planners will try to maintain maximum flexibility. For example, if shuttle flights are backed up and have to be postponed, planners will examine the possibility of shifting AP in the meantime to another user. Another option to be investigated is whether some payloads could be moved from the shuttle to unmanned rockets using half as much AP or less.

However, says Adm. Richard H. Truly, NASA's associate administrator for space flight, "remanifesting and delay of some space shuttle flights are probable" next year. NASA will focus on a series of flights to carry "our most precious payloads"—bearing major scientific missions such as Magellan and the Hubble Space Telescope. Moreover, the working group projects insufficient supplies of AP for some planned flights of Titan IV and Titan 34D.

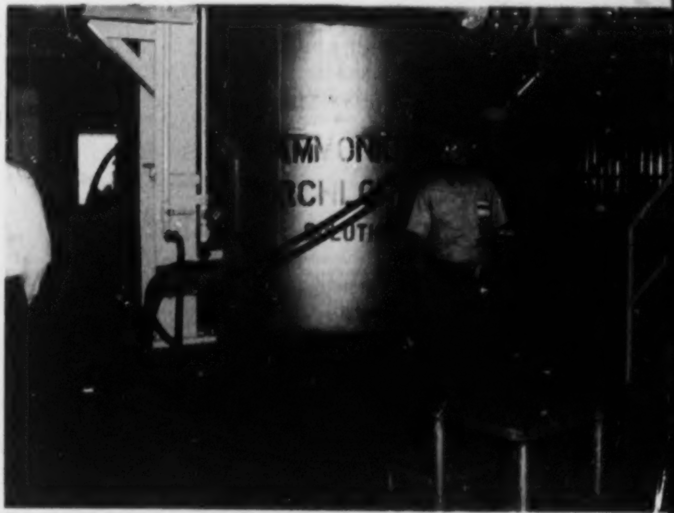
Federal officials have also looked at a longer-term possibility—enlisting a third AP producer—going so far as to talk to two firms that used to make AP, according to an industry source. However, the firms were not interested. Indeed, several observers doubt the market would be profitable if split among three companies. Import of AP from abroad is also not considered a viable option, since foreign production capacity is relatively small.

C&EN staff photo

Water Street runs through center of Henderson, Nev.

In any case, the centerpiece of the recovery program is expansion by Kerr-McGee and rebuilding of a plant by PEPCON. By a small modification—eliminating the redissolving and reuse of "screen reject" AP particles from customers--Kerr-McGee expects to be able to raise the capacity of its current plant from 36 million up to 40 million lb a year. In addition, it plans to build a new plant with 20 million lb-a-year capacity, using the same process, at some site remote from Henderson.

Both this plant and a 40 million lb-per-year plant to be built by PEPCON will benefit from federal aid. The two firms will borrow funds on their own for construction, and the loan will be repaid over seven


C&EN staff photo

Workers enter Kerr-McGee's AP plant with hard hats, safety goggles, respirators, and safety galoshes

Photo by Raymond C. Rhees

At wrecked PEPCON plant, polyethylene drums burned away, leaving behind unreacted piles of AP stored in them

years through a surcharge on each pound of AP sold, based on sales of 20 million lb a year. The federal government guarantees to pay any unamortized amount at the end of seven years.

PEPCON is moving ahead rapidly with its rebuilding plans. Gibson stresses that the firm has committed itself in writing to NASA, DOD, and Thiokol to start producing AP in six months, by Feb. 1.

To build and run the new plant, American Pacific organized a new subsidiary, PEPCON Production Inc. (PPI). PEPCON is likely to be tied up in litigation over damage suits for years, and carried liability insurance of only $1 million. Bankruptcy is a distinct possibility. The new subsidiary signed a license agreement buying PEPCON's technology for a royalty of $0.005 per lb of production.

Late last month, the firm selected a remote, 4800-acre mountain valley site 15 miles west of Cedar City, Utah. There is only a dirt road to it, but it has a railroad line, power lines, and a water source. The site is about 175 miles from Henderson, notes Rhees, but beat out two remote Nevada sites because construction could proceed there on the required expedited basis. A few days earlier, a special session of the Utah legislature approved a $33 million industrial revenue bond issue to finance construction of the plant. Design and construction, at an estimated cost of $23 million, will be carried out by Stearns-Rogers.

Several sources express great skepticism that PEPCON can build the plant and start production within six months, one calling the idea "preposterous" and saying it should take at least 12 to 18 months. However, Gibson explains, several measures will expedite his plans.

For one thing, the company will initially buy sodium chlorate, which is readily available, and convert it to sodium perchlorate and then to AP at the new plant. Eventually, the firm will make feedstock sodium chlorate at another site, in southern Nevada, so it can take advantage of low-cost power from Hoover Dam, according to Rhees. The major power cost in preparing AP is adding three oxygen atoms to sodium chloride to form sodium chlorate, he points out. Putting on the fourth oxygen to make the perchlorate in Utah will cost much less. PEPCON will then transport the sodium chlorate in solution to Utah, a less hazardous method than transporting the solid.

Moreover, Gibson says, the plant does not have to be complete initially. It can be built in modular form—installing, for example, half the crystallizers initially and adding the rest later. The plant will use the same process and design plans as the destroyed plant, with introduction of more automated process control. PEPCON has a large cadre of personnel familiar with the plant design and operation. Initially, the plant will employ about 70 people, growing later to 150.

In response to skeptics, Gibson also emphasizes that PEPCON is committed to furnish product "meeting specifications" within six months, but that period does not include qualification of the product. He expects, for instance, that NASA will insist on a full set of tests to qualify AP for use in shuttle booster rockets, from lab to full scale, which could take at least several months.

Possible delays, stretchouts, and cancellations in space and missile programs due to a shortage of AP have aroused great concern among rocket users and manufacturers, rocket fuel makers, and their insurance companies. For example, PEPCON has been the sole source of AP for Aerojet-General Corp., maker of Stage 2 of the MX missile, and the Hawk, Standard, Maverick, and other missiles. Aerojet has enough AP on hand for the near future. But if PEPCON does not start producing on Feb. 1 as it says it will, "there could be problems," Aerojet says.

As for the months of qualification tests a new PEPCON plant might face, "you can speed up the qualification process if there's a national emergency," an Aerojet spokesman points out. His firm is also looking into possible supply from Kerr-McGee.

Meanwhile, potential participants in the fledgling U.S. commercial space launch industry are deeply concerned about what priority commercial space launches will receive in allocations of limited AP. For example, satellite maker Hughes Aircraft Co. has contracted with rocket manufacturers Martin-Marietta and McDonnell-Douglas to use their commercial launch vehicles, the Titan III and Delta II, respectively, to put British and Japanese direct broadcasting satellites into orbit. If the British launch, scheduled for August 1989, is delayed, Hughes stands to lose $100 million on a deferred payment contract. Delay of six to 12 months in the July 1989 Japanese launch could cause losses of $70 million or more.

Hughes says it hasn't received a definitive answer yet. But there are indications that when the interagency working group meets in September to plan AP allocations for the first half of 1989, the group will try to accommodate commercial launches, especially where the future of a business may be at stake.

The blasts at PEPCON on May 4 had a dramatic impact not only on national needs and issues. They also injured some 350 local residents, caused harm to property up to 20 miles away, and did some damage to more than 50% of Henderson's 17,000 residential and commercial buildings. The two largest blasts registered 3.0 and 3.5 on the Richter scale hundreds of miles away in California, notes Nevada Gov. Richard H. Bryan. Cars were crumpled, doors blown off their hinges, and windows shattered for miles around. Particularly hard hit was the Green Valley subdivision, just a mile and a half from PEPCON.

City Manager Gary Bloomquist puts uninsured losses at more than $20 million, plus $3 million more in insurance deductibles. Just as serious, he says, were the psychological and emotional impact of the explosions, on schoolchildren and adults alike. And many residents call the disaster "miraculous," because a chain of lucky events prevented almost all loss of life or more serious damage.

The disaster brought a kind of end to innocence for some residents, an awareness for the first time of the presence and potential hazards of chemical plants, and the need for more regulation and oversight. These feelings of concern and fear—particularly about the presence of the Kerr-McGee plant, just 0.7 mile from the center of town—were vehemently expressed by several local citizens and leaders at a hearing a few weeks ago in Henderson, held by the Subcommittee on Investigations & Oversight of the House Committee on Science, Space & Technology. The committee and subcommittee chairman is Rep. Robert A. Roe (D.-N.J.).

For example, Pamela Walz, a Green Valley resident, described the traumatic events of May 4 and $7500 in damage done to her 10-month-old house, and admitted that she had never before heard the names PEPCON and ammonium perchlorate. Next, she discovered that there was another plant in Henderson, Kerr-McGee's, that made the same product. Then she learned that "there are many chemical companies in the industrial complex, but no one had any idea what they manufactured."

C&EN staff photo

AP is stored outdoors in 30- and 50-gallon barrels at Kerr-McGee to await blending to desired specifications

She realized that the tankcars on the Union Pacific Railroad spur that served PEPCON and other chemical firms also ran by her house several times a day. She contacted several government agencies until she obtained a list of some of the chemicals transported. And she concluded that "no government agency on any level has the ability at this time to monitor the transportation, manufacture, or storage of chemical compounds in this state. The few regulations we do have regarding safety and environmental concerns are flagrantly violated because the penalties are insufficient."

Echoing the opinion of many others, Walz noted that she supports strong defense and space programs. However, she does not believe she and her fellow residents should have to bear alone the risk and financial burden of chemical disaster. "I was never given a choice on whether to risk the health and safety of my family. I feel that we can produce ammonium perchlorate in Nevada, and possibly in Clark County [her county]. But not in the middle of a city of 56,000 residents."

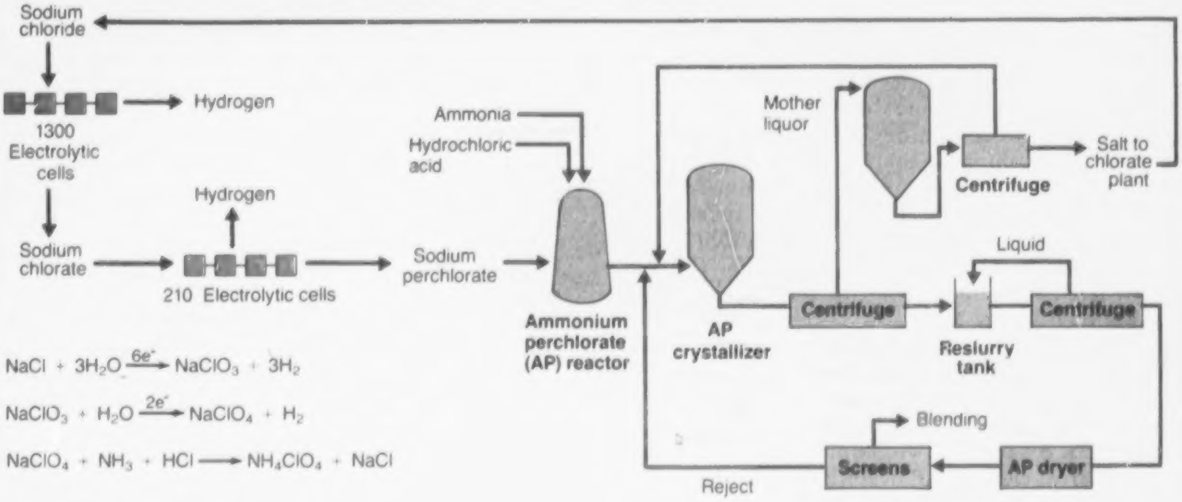
What particularly upset her and other Henderson residents was that, on the one hand, NASA and DOD have "irresponsibly" decided to give a subsidy of tens of millions of dollars for rebuilding the PEPCON plant and constructing an additional Kerr-McGee plant, "without stipulating safety factors regarding the plant employees and the community." But on the other hand, the Federal Emergency Management Agency (FEMA), after three visits to Henderson, has denied any disaster aid to local residents.

Her words were reinforced by those of Brian Greenspun, president of the *Las Vegas Sun* newspaper, expressing, he said, "a consensus" of local residents. Few other communities have been asked to give so much or to take such risks as Nevadans have in the name of patriotism, he says. The state's land is 87% owned by the federal government. It has hosted aboveground and underground nuclear testing, the Nellis Air Force weapons training base, and now it is having pushed on it a nuclear waste disposal dump at Yucca Mountain.

Nevadans are being asked to "accept the unacceptable risks of living amidst the production of ammonium perchlorate, whose explosive potential has been demonstrated in living color on the television sets of the world," Greenspun continues. "The people of Las Vegas are frightened," he adds. They are no longer willing to accept the assurances of government, particularly when those who have lost their life savings or even just had to pay their insurance deductibles are told that "the risk of such explosions is theirs alone and not to be shared by the government in whose name these plants exist." And he urges a government financial package to move the AP plants to a safer, more remote site.

Roe and his staff aides have made considerable efforts to arrange financial aid for Henderson residents who suffered damage from the disaster, as has Rep. James H. Bilbray (D.-Nev.), who represents the area in Congress. Roe wrote in June to President

Kerr-McGee uses two electrolysis steps and double-decomposition reaction to make ammonium perchlorate



$NaCl + 3H_2O \xrightarrow{6e^-} NaClO_3 + 3H_2$

$NaClO_3 + H_2O \xrightarrow{2e^-} NaClO_4 + H_2$

$NaClO_4 + NH_3 + HCl \longrightarrow NH_4ClO_4 + NaCl$

Kerr-McGee Chemical Corp. uses several unit processes to produce ammonium perchlorate (AP). First, in a continuous process using large holding tanks, sodium chloride is electrolyzed to sodium chlorate in some 1300 cells. By-product hydrogen, containing a trace of chlorine, is vented to the atmosphere. The chlorate is crystallized out, redissolved, and then electrolyzed further to produce sodium perchlorate in a batch process in some 210 cells. Sodium dichromate is added to enhance cell efficiency. The perchlorate is filtered out and purified. AP is then produced from sodium perchlorate, anhydrous ammonia, and hydrochloric acid by a double-decomposition reaction. In a vacuum crystallizer—operated so as to produce the desired particle size—AP precipitates and sodium chloride stays in solution. AP crystals are centrifuged out, reslurried, and pumped to a remote building for drying and screening. Finally, AP is blended to specifications for particle size and purity, packaged, and shipped. By-product sodium chloride returns to the sodium chlorate plant for reuse.

Reagan, urging that FEMA grant disaster relief. "A community that supports two of the most important plants in the country has suffered misfortune as the result of that support and should be treated with compassion and concern," Roe wrote.

Nevertheless, FEMA denied such aid. Roe and Bilbray, therefore, are now preparing to submit bills to grant compensation to local residents for some $2.5 million in insurance deductibles. In addition, Roe and his staff have been working to persuade the Nevada state legislature to aid the victims. At a meeting this week, the state's interim finance committee will consider compensating the Henderson city government and the Clark County school system for between $400,000 and $600,000 in damages and services related to the disaster.

The remaining segment of the population not yet covered is those who were uninsured. Also through the offices of Roe and Bilbray, Kerr-McGee announced late last month formation of a $293,000 loan guarantee program to offer 10-year loans at favorable interest to uninsured residents and businesses who suffered damage from explosion of the PEPCON plant. PEPCON is working on setting up such a fund, but its poor financial position has prevented it so far from working out an arrangement with local banks.

Kerr-McGee's decision to create the fund, despite its lack of connection with the May 4 explosions, is part of a recent policy by the firm of reaching out to better its relations with the local community. After the PEPCON disaster, local pressure forced Kerr-McGee to shut down its AP plant for several weeks while an independent safety panel inspected the facility and recommended changes. There was even concern in Congress and elsewhere that local residents might seek injunctions to keep the plant closed, and discussion of whether the federal government might have to invoke national emergency powers to keep open the only source of AP in the U.S. Considerable local sentiment still wants the plant moved out of town.

Before reopening in June, the plant adopted eight improvements urged by the safety panel, and it is now working on others of a longer-term nature. The plant is also increasing the dispersal of barrels of AP stored outdoors, as requested by local fire officials. And it is buying an additional blender to expedite shipments and enable reduction of stored inventory on site.

In late June, Kerr-McGee invited local media in to tour and photograph its AP plant and to interview plant managers. The managers put great emphasis on all the safety measures at the plant. And they indicated that the media visit was a "first step on the trail of being more open."

Furthermore, Kerr-McGee has hired an advertising agency to help get the firm "more involved with the community"—including newspaper ads to better its image—and to give it more feedback on community concerns. And the firm plans to seek cooperation from DOD, the Department of Transportation, NASA, academia, and rocket motor makers for joint studies on a large scale to determine safe ammonium perchlorate storage and shipping practices.

However, Kerr-McGee's efforts to maintain a safe image were not aided by its citation, just revealed last week, for seven alleged violations and $5200 in fines by the Nevada Division of Occupational Safety & Health (DOSH), which fills the role of the federal Occupational Safety & Health Administration in Nevada. One "willful" violation involved exposing workers to "increased likelihood of fire and explosion hazards" by manufacturing, processing, and storing AP in areas with potential for contamination with organic materials. A "serious" violation involved not keeping work areas clean of AP in spills, leaks, and dust.

Kerr-McGee was also cited for exposing employees to the "likelihood of fire and explosion hazards" by storing AP improperly: 26 million lb were stored in piles in close proximity outdoors and on asphalt pads. "AP and asphalt are incompatible," DOSH says, because asphalt must be kept away from strong oxidizers. Kerr-McGee has taken action to correct six of the seven violations, but will appeal the asphalt charge.

Meanwhile, DOSH has also just cited PEPCON for 30 alleged safety violations and levied $36,455 in fines, on the basis of an investigation since the disaster about conditions before it. Several of the violations resemble charges hurled at PEPCON in the controversy over what caused the disaster.

Thus, the four "willful" citations include lack of manufacturing controls and standard operating procedures that caused employee exposure to "increased likelihood of fire and/or explosion"; and lack of emergency evacuation and response procedures for workers in event of an accident. One of the nine "serious" violations was improper storage of large quantities of AP, in disregard of safe quantity/distance requirements, and storage on asphalt pads. Gibson says that PEPCON will appeal the charges, terming them based on "unsubstantiated allegations."

Probably the greatest source of controversy in Henderson now is what caused the disaster at PEPCON, with millions of dollars in liability lawsuits riding on the outcome. Indeed, the first personal injury suit was filed on May 5, the day after the disaster. An independent panel sponsored by the local fire department is analyzing the origin and propagation of the fire and explosions. Investigations are also being done by an independent panel engaged by PEPCON and its insurance company, by other insurance companies, and by Southwest Gas Corp.

In mid-July, the Clark County Fire Department issued a one-and-a-half page interim report, blaming a combination of factors for the disaster—welders cutting in a hazardous area with no fire watch, highly combustible structural components (glass-fiber reinforced plastic), high-density storage of "a highly flammable and detonable material," spilled AP lying around, and high-velocity wind conditions.

According to the report, PEPCON welders working at the west end of the batch dryer house sprayed iron slag, igniting combustible construction components, product process equipment, and residual AP in and around the batch house. The fire immediately spread "along available fuel surfaces," and by thermal expo-

Two firms qualify to supply perchlorate for rockets

System for which qualified	PEPCON	Kerr-McGee
Shuttle booster	●	●
Titan IV	●	
Titan 34D	●	●
IUS[a]	●	
Delta II		●
Peacekeeper (MX)		
Stage 1		●
Stage 2	●	
Stage 3		●
Small ICBM[b]		●
Minuteman		●
Trident D-5		●

[a] Inertial Upper Stage rocket, used for launches from space shuttle. [b] Intercontinental ballistic missile. Source: Department of Defense

Variety of rockets and missiles use ammonium perchlorate

AIR FORCE
- Advanced medium range air-to-air missile (AMRAAM)
- Air-to-Ground Missile (AGM-130)
- Delta II
- Inertial Upper Stage
- Maverick
- Minuteman
- Peacekeeper (MX)
- Sensor-Fused Weapon
- Short-range attack missile (SRAM II)
- Small intercontinental ballistic missile
- Titan 34D
- Titan IV

ARMY
- Chapparral
- Hawk
- 155MM high explosive shell
- Multiple launch rocket system (MLRS)
- Patriot
- Stinger
- Tactical missile system (ATACMS)

NAVY
- Harpoon
- High-speed antiradiation missile (HARM)
- Mk 46 Torpedo
- Mk 57 Bomblet
- Mk 48 Torpedo
- Mk 6/JATO (jet-assisted take off)
- Mk 23
- Mk 66
- Phoenix
- Quickstrike mine
- Rolling airframe missile
- Sidewinder
- Smokey Sam
- Sparrow
- Standard Missile Motors
- Sub-Launched Mobile Mine
- Tomahawk Cruise Missile
- Trident D-5

NASA
- Shuttle booster

Source: Department of Defense

Ammonium perchlorate use in rockets projected to reach 68 million lb by 1990. . .

Millions of lb	1988	1989	1990	1991	1992	1993	1994
Army	9.3	14.0	11.7	9.1	9.1	9.4	10.3
Navy	3.7	6.5	5.4	5.1	5.1	5.1	5.1
Air Force	11.0	11.5	16.1	12.9	10.0	10.0	10.0
NASA	8.5	19.8	22.1	24.2	28.0	31.3	29.7
Commercial space launches[a]	3.5	3.7	5.2	0.4	1.0	0.6	0.6
EMLRS[b]	1.8	2.6	5.3	5.3	7.0	5.3	5.3
Other export	1.0	2.0	2.0	2.0	2.0	2.0	2.0
TOTAL	38.8	60.1	67.8	59.0	62.2	63.7	63.0

a Use for commercial launches expected to grow in 1990s, but numbers available so far show only small demand. b European Multiple-Launch Rocket System. Source: Department of Defense

. . .with shuttle booster taking the largest share

Millions of lb	1989
Shuttle solid rocket booster	18.8
Multiple launch rocket system (MLRS)	12.6
Titan IV	5.7
Minuteman	2.5
Standard missile	1.9
Trident D-5	1.5
Peacekeeper (MX)	1.6
Patriot	1.3
Delta II (GEM)	1.0
High-speed antiradiation missile (HARM)	0.8

Source: Department of Defense

sure and wind velocity spread to the adjacent storage of "high-density combustible containers of potentially detonable material." Several low-order explosions occurred, and the intense temperatures and direct flame impingement resulted in two major detonations in large aluminum tote bins holding up to 5000 lb of AP each.

Fire chief Roy L. Parrish tells C&EN that a consulting laboratory is running tests to determine the behavior of the materials involved, and the exact mechanism of the detonations. A detailed final report on the causes is due in mid-September.

Both PEPCON and the United Steelworkers Union local representing the welders and other company employees reject the interim findings. PEPCON says some of the findings "are inconsistent with the facts," and others "are inconsistent with established scientific data." For example, the firm believes the fire started at the east end of the batch house, 60 to 80 feet away from where the welders were.

A crucial element of contention is the properties of AP. PEPCON officials emphasize that AP is "an oxidizer that does not burn." When heated, "it provides oxygen to enable other materials that do burn to do so." If heated in a fire, notes Rhees, it contributes to the fire by releasing oxygen. Only when it gets to higher temperatures, approaching 430 to 450 °C, does it decompose violently. So the question is, he says, what was the fuel source that allowed the AP at PEPCON to get hot enough to explode?

The only fuel source known to be present in sufficient quantities was natural gas, PEPCON says. There was an underground 16-inch high-pressure gas main traversing the plant. "There is evidence of the presence of a large leak in the area preceding the incident," PEPCON maintains.

On May 4 there was a massive rupture several feet long in the gas line, with flames shooting 60 or 80 feet into the air from both ends of the rupture. And there is extensive evidence of fire emitting from the ground throughout the plant. In addition, PEPCON says, there is an abundance of physical evidence around the plant indicating the presence of natural gas fires.

"So it's not a question of whether there was a gas leak, but when it took place," says Gibson. There is considerable evidence, he notes, that there might have been a slow, small gas leak for up to two weeks before, possibly saturating the ground under the plant. A fire could easily start from such gas seeping out of the ground. Gibson says he expects in the near future to assert "a substantial claim for the company's losses in excess of insurance coverages against the party or parties responsible."

Southwest Gas retorts that "there is no evidence of any natural gas leak." Parrish confirms that the panel engaged by the fire department pressure tested all the gas lines at 10, 50, and 300 psi, and found no leaks except at the site of the massive breakage. Southwest asserts that its natural gas line was "the victim and not the cause of the blasts."

Southwest adds that research into the properties of AP indicates that only a very limited fuel source was necessary to trigger the initial explosion at PEPCON. There were numerous sources of fuel around, such as plastics, wood, hydrogen, glass fiber, welding gases, and contaminated AP. The initial explosion and fire could then have resulted in setting off the large quantities of AP stored on the site.

Until now, AP has been classified as an oxidizer, not an explosive, for purposes of transportation, handling, and storage. For example, the Department of Transportation (DOT) lists AP as an oxidizer for particle sizes greater than 15 µm, and as an explosive only at under 15 µm. PEPCON and Kerr-McGee work with far larger sizes (starting with 90 µm at PEPCON, for instance).

However, in light of the PEPCON disaster, re-evaluation of AP's properties and reclassification is being sought. Further testing is likely, according to several sources. For example, Bruce L. Woodbury, a county commissioner in Clark County, has written to the Air Force asking that AP be re-evaluated to see whether it should be reclassified as an explosive under applicable fire codes and standards. And DOT's Office of Hazardous Materials Transportation is waiting for determination of the causes of the PEPCON explosions before deciding whether to re-evaluate safety requirements for AP transportation. □

Chemical company earnings continued spectacular growth in second quarter Page 10

A1250-1
8/18/88

AUGUST 15, 1988
CHEMICAL & ENGINEERING
NEWS

0511179C098 9 K AR6633SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Fluorine-18

Imaging the brain for Parkinson's disease studies
Page 26

Volume 66, Number 33
CENEAR 66 (32) 1–48
ISSN 0009-2347

CHEMICAL & ENGINEERING
NEWS
AUGUST 15, 1988

News of the Week

- **First joint U.S.-Soviet nuclear arms test is set to take place this week at Nevada Test Site. Page 4**
- **Italy's Montedison and ENI will merge their chemical interests into a new, huge chemical company to be called Enimont. Page 5**
- **EPA's proposed standard to reduce lead levels in drinking water has drawn some criticism. Page 5**
- **New AIDS drug genetically engineered to slow the spread of human immunodeficiency virus (HIV) has begun tests in humans. Page 6**
- **The U.S.-Canada free trade agreement has passed Congress, bringing a North American Common Market a step closer. Page 6**

Cover: Positron emission tomographic image of the brain of a patient with Parkinson's disease shows lower-than-normal accumulation of a fluorine-18-labeled dopamine analog in the putamen (pink region). Photo courtesy of E. Stephen Garnett, Chedoke-McMaster Hospitals, Hamilton, Ontario

Letters 2

Concentrates
Business 7
Government 16
Science/Technology 21

The Departments
People 33
Newscripts 48

Business

Earnings of leading U.S. chemical companies shot up 70% in the second quarter, the fourth straight period in which the increase was more than 50%. **Page 10**

Government

OSHA's proposed revision of exposure levels for hazardous chemicals is taking some hard knocks in public hearings. **Page 17**

The safety of the Pentagon's chemical and biological arms research program is being strongly questioned by a Senate subcommittee, other groups. **Page 19**

Science

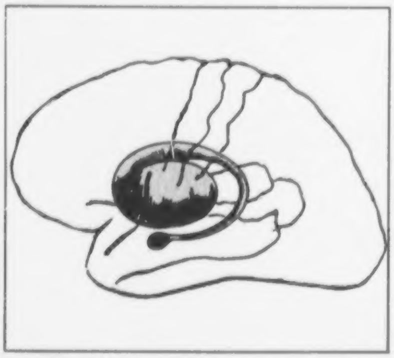
"**Gmelin Handbook of Inorganic Chemistry**" flourishes 200 years after birth of its founder, Leopold Gmelin, whose birthday this month is marked by issuance of West German postage stamp. **Page 22**

Education

Disabled students complete hands-on research program held at East Carolina University, Greenville, N.C., this summer. **Page 25**

ACS News

Chemical professionals are still being hit by major staff reductions in spite of the industry's sharply improving financial fortunes. **Page 31**



Technology

Safe, noninvasive ^{18}F positron emission tomography is advancing imaging of the human brain, gives new insights into metabolism of dopamine in brain of parkinsonian patients through use of labeled fluorodopa tracer. Page 26

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 47)

LETTERS

Broaden chemical education

SIR: As a graduate of McGill University (B.S. 1985) and a native of Montreal, I was pleased to see the feature article on chemistry education for the public (C&EN, June 20, page 29) for several reasons.

I have felt for a long time that the fine work of David Harpp, Ariel Fenster, and Joseph Schwarcz has long deserved national, if not international attention. As an undergraduate in their course, "The World of Chemistry," I had a difficult time with my peers in other branches of science, and especially arts, because as a chemistry honors student they suspected that I possessed an unfair advantage with respect to the material. This assumption was quickly proved false, as I, too, had to study very hard to absorb the large quantity of information on the chemistry that surrounds us everywhere in our daily lives.

Now, as a chemistry graduate student, I am even more able to appreciate the importance of that training, whether it is in the laboratory or at home. It is vital that chemists get their noses out of their books and away from their computers long enough to realize that we have a responsibility to educate those around us and remove much of the stigma surrounding chemists and their work.

On another note, I am disappointed that it took an international chemical congress held in Canada to draw the well-deserved attention to these programs that have been in existence for almost a decade. As a Canadian citizen studying in the U.S., I am often saddened by the relatively little coverage given to the outstanding science performed at many Canadian universities. I hope American chemists can learn a lesson from their neighbors "up North" and make a more concentrated effort to broaden the chemical education of the public.

Debra R. Luffer
Indiana University, Bloomington

A vote for Madam Chairman

SIR: I can't resist coming out of the Pandora's box opened by Donald Paulson (C&EN, June 13, page 5). Paulson wants to be called a chair. That's all right, I suppose, as long as one understands the context. But why burden a fine little word like chair with multiple meanings, and thus add to its potential for ambiguity?

Continuing with our trivial pursuits, let me repeat what the parliamentarians said concerning such words. From the 20th convention of the National Association of Parliamentarians in San Francisco came the following: "Whereas, parliamentary law has a language all its own; and whereas, in olden times the one presiding was the only person provided with a chair, while others sat on benches, hence he was called the Chairman: and whereas, since time immemorial the term 'Mister Chairman' or 'Madam Chairman' has always been employed to differentiate between sexes; and whereas, further effort toward sex differentiation is redundant and contrived; now therefore be it resolved that organizations and parliamentarians of the National Association of Parliamentarians must use the term Chairman instead of 'Chairperson,' and be it resolved that all members of the National Association of Parliamentarians should habitually stress the principle that the word Chairman belongs to the title of the office the same as the title of President or Secretary."

The above was submitted to "Dear Abby" in November 1983 by a woman, who went on to say that "a person should not be more concerned with his or her sex than the position held. Besides, it sounds contrived and unprofessional." Abby said that the resolution gets her vote.

W. T. Burr Jr.
Asheville, N.C.

Chemical weapons

SIR: We would like to comment on Harold B. Reisman's letter about chemical weapons (C&EN, April 25, page 2). The use of chemical weapons by Iraq has been proved by United Nations' teams of specialists several times.

But the key players in the Security Council, who are supplying Iraq with chemical weapons technology, did not let the Security Council condemn Iraq by name for the use of chemical weapons.

Staff and faculty members
Chemistry Department
Isfahan University of Technology, Iran

Correction

- July 25, page 5: Forensics Sciences Associates, Emeryville, Calif., is not a subsidiary of Cetus Corp., though it does collaborate with Cetus on some research projects.

Chemical Earnings Continue On Hot Streak in Second Quarter

William J. Storck,
C&EN Northeast News Bureau

Earnings at leading chemical companies continued their strong growth in this year's second quarter, adding to a string of several quarters showing superb performance. It marked the ninth consecutive quarter of double-digit earnings growth and the fourth straight period in which the rise was more than 50%.

The combined after-tax earnings from continuing operations of 30 major chemical firms climbed 70% in the second quarter, compared with last year's second quarter. And chemical earnings at oil and natural gas companies and diversified corporations that also produce chemicals also were up markedly.

There continues to be one simple reason for the vastly improved earnings at companies whose major business is production of chemicals: improved business—both domestic and foreign.

Demand for chemicals is up substantially. According to the Commerce Department, shipments of chemicals and allied products in the second quarter rose 13% from the same period last year to a seasonally adjusted $60 billion. And for industrial chemicals, the increase was a greater 14% to a seasonally adjusted $15.8 billion.

Production of chemicals and allied products in the second quarter, according to government data, rose a seasonally adjusted 8% over second-quarter 1987, causing the government's measure of theoretical capacity utilization to average more than 86% for the quarter. Chemical producers, and especially those making basic chemicals, agree that capacity use is much higher than the

Chemical industry leaders for the second quarter . . .

Sales			
Rank 1988		$ Millions	Rank 1987
1	Dow Chemical	$4252.0	1
2	Monsanto	2263.0	2
3	Union Carbide	2130.0	3
4	W. R. Grace	1447.0	4
5	American Cyanamid	1246.3	5
6	Quantum Chemical	734.5	8
7	Hercules	704.7	6
8	Rohm & Haas	700.1	7
9	Arco Chemical	676.0	11
10	B. F. Goodrich	621.7	10

Earnings[a]		
	$ Millions	Rank 1987
Dow Chemical	$636.0	1
Monsanto	220.0	2
Union Carbide	187.0	5
Arco Chemical	126.0	4
American Cyanamid	99.5	3
Quantum Chemical	85.1	13
Rohm & Haas	75.8	6
W. R. Grace	58.2	10
Ethyl	56.9	8
B. F. Goodrich	56.6	12

Profitability		
	Earnings as % of sales	Rank 1987
Arco Chemical	18.6%	2
Georgia Gulf	17.2	5
International Flavors	16.6	1
Vista Chemical	16.2	17
Dow Chemical	15.0	10
First Mississippi	14.9	4
Aristech	13.2	15
Loctite	11.7	8
Quantum Chemical	11.6	28
Ethyl	11.5	3

. . . and for the first six months of 1988

Sales			
Rank 1988		$ Millions	Rank 1987
1	Dow Chemical	$8233.0	1
2	Monsanto	4390.0	2
3	Union Carbide	4077.0	3
4	W. R. Grace	2744.0	4
5	American Cyanamid	2394.8	5
6	Quantum Chemical	1567.4	7
7	Hercules	1366.0	6
8	Rohm & Haas	1320.6	8
9	Arco Chemical	1259.0	12
10	Air Products	1223.9	9

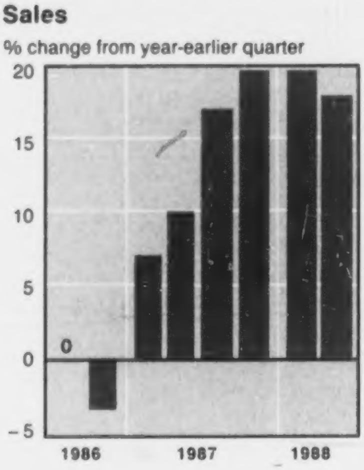
Earnings[a]		
	$ Millions	Rank 1987
Dow Chemical	$1143.0	1
Monsanto	430.0	2
Union Carbide	288.0	4
Arco Chemical	234.0	5
Quantum Chemical	185.6	11
American Cyanamid	178.7	3
Rohm & Haas	138.0	6
Ethyl	110.0	8
Air Products	108.0	9
W. R. Grace	96.9	12

Profitability		
	Earnings as % of sales	Rank 1987
Arco Chemical	18.6%	2
Georgia Gulf	17.3	8
Aristech	16.6	16
International Flavors	16.3	1
Vista Chemical	15.7	15
Dow Chemical	13.9	8
Quantum Chemical	11.8	24
Ethyl	11.3	3
Betz Laboratories	10.7	4
Loctite	10.7	6

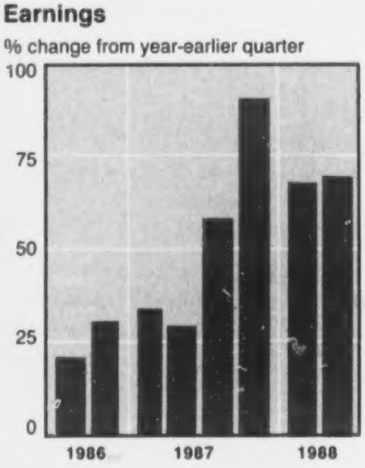
Note: Based on 30 companies listed on page 12. a After taxes.

Chemical industry second-quarter 1988 results

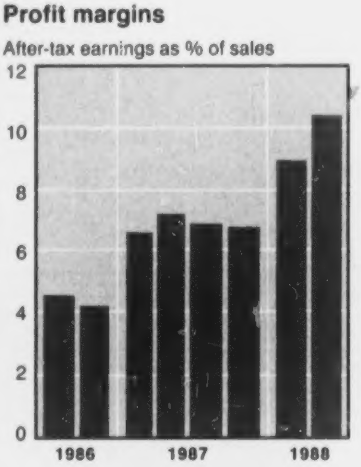
- Sales climbed 18%
- Earnings soared 70%
- Profit margins at 10.3%
- Production rose 8%
- Prices increased 8%


Sales

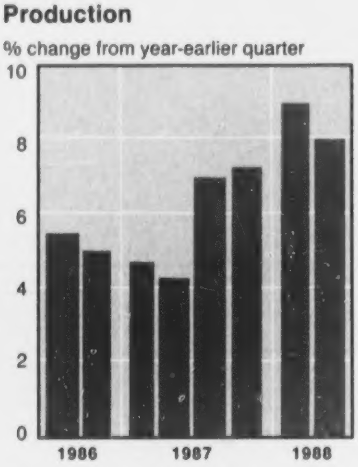
% change from year-earlier quarter


Earnings

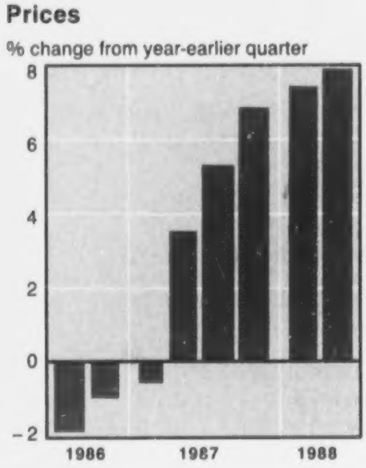
% change from year-earlier quarter


Profit margins

After-tax earnings as % of sales

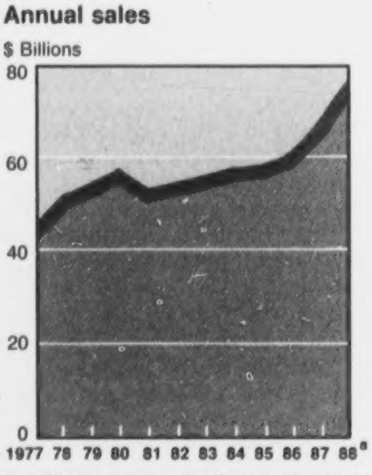

Production

% change from year-earlier quarter

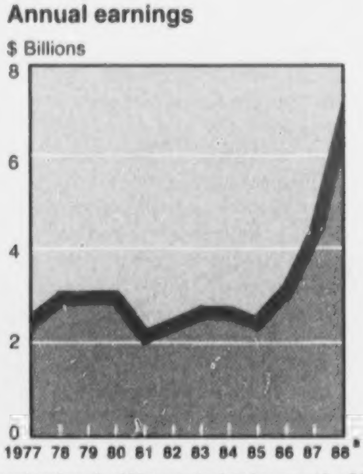

Prices

% change from year-earlier quarter

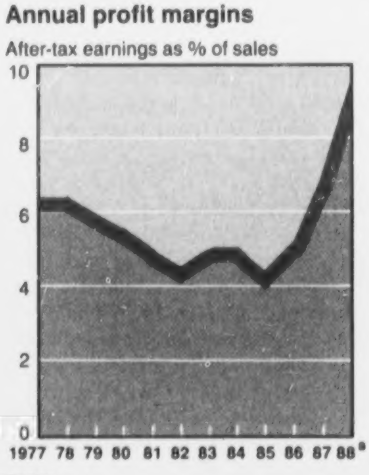
Sales in 1988 will climb about 15% as earnings jump 60%, pushing profit margins to 9.5%


Annual sales

$ Billions


Annual earnings

$ Billions


Annual profit margins

After-tax earnings as % of sales

Note: All sales, earnings, and profit margin data are based on combined results of 30 companies listed on page 12. a C&EN estimates.

Profitability improves greatly at leading U.S. chemical companies

	SECOND-QUARTER 1988						FIRST-HALF 1988			
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings[a]
Air Products[c]	$ 605.1	$ 52.3	15%	18%	8.6%	8.4%	$ 1,223.9	$108.0	16%	33%
American Cyanamid[c]	1,246.3	99.5	15	31	8.0	7.0	2,394.8	178.7	14	30
Arco Chemical[c]	676.0	126.0	37	80	18.6	14.2	1,259.0	234.0	34	81
Aristech	268.4	35.3	17	119	13.2	7.0	528.7	88.0	21	197
Betz Laboratories	111.9	12.0	15	19	10.8	10.4	217.7	23.2	17	17
Cabot[c]	423.8	16.6	20	14	3.9	4.1	889.7	35.0	21	38
Chemed	108.1	6.1	9	15	5.6	5.4	207.8	10.6	9	11
Crompton & Knowles	78.4	5.1	21	40	6.5	5.6	142.0	8.6	18	44
Dow Chemical[c]	4,252.0	636.0	25	102	15.0	9.2	8,233.0	1143.0	28	104
Ethyl[c]	493.4	56.9	17	19	11.5	11.4	973.4	110.0	20	17
First Mississippi	90.9	13.5	1	40	14.9	10.8	153.3	14.8	−5	23
H. B. Fuller	172.8	5.7	14	−18	3.3	4.6	327.4	10.4	13	−2
Georgia Gulf	276.4	47.5	58	161	17.2	10.4	498.3	86.1	51	200
B. F. Goodrich[c]	621.7	56.6	18	113	9.1	5.0	1,186.7	95.6	20	201
W. R. Grace[c]	1,447.0	58.2	26	62	4.0	3.1	2,744.0	96.9	30	103
Hercules[c]	704.7	47.3	2	−22	6.7	8.8	1,366.0	87.1	1	−20
International Flavors	234.2	38.8	17	25	16.6	15.5	458.2	74.7	21	28
International Minerals	262.7	29.6	−43	1038	11.3	0.6	585.5	61.6	−36	191
Loctite	110.8	12.9	15	35	11.7	9.9	219.7	23.4	18	29
Lubrizol	284.5	20.0	7	−3	7.0	7.8	577.7	39.1	7	−8
Monsanto[c]	2,263.0	220.0	12	43	9.7	7.6	4,390.0	430.0	13	47
Nalco Chemical	247.4	26.0	22	32	10.5	9.8	483.4	51.0	23	35
Olin[c]	578.0	29.0	19	32	5.0	4.5	1,145.0	58.0	19	23
Pennwalt	327.9	14.7	10	7	4.5	4.6	656.3	28.3	17	9
Petrolite	76.0	3.7	11	−10	4.9	6.0	155.5	8.4	17	3
Quantum Chemical[c]	734.5	85.1	33	287	11.6	4.0	1,567.4	185.6	30	265
Rohm & Haas[c]	700.1	75.8	17	22	10.8	10.4	1,320.6	138.0	17	15
Union Carbide[c]	2,130.0	187.0	28	171	8.8	4.2	4,077.0	288.0	22	113
Vista Chemical	186.3	30.1	16	184	16.2	6.6	404.9	63.4	30	190
Witco[c]	405.3	22.7	14	29	5.6	4.9	799.2	42.7	16	31
Total 15 larger companies	**$17,280.9**	**$1789.0**	**21%**	**71%**	**10.2%**	**7.2%**	**$33,569.8**	**$3230.5**	**21%**	**71%**
Total 15 smaller companies	**$ 2,836.8**	**$ 301.1**	**7%**	**65%**	**10.6%**	**6.8%**	**$ 5,616.5**	**$ 591.8**	**9%**	**69%**
GRAND TOTAL	**$20,117.7**	**$2070.1**	**18%**	**70%**	**10.3%**	**7.2%**	**$39,186.3**	**$3822.3**	**19%**	**70%**

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. c One of the 15 largest companies.

government figures show. For some commodity chemicals, in fact, plant use rate is 100% or higher, they say. As a result of the increasing demand, and tightening capacity situation, producers have placed many commodity chemical products—especially petrochemicals—on allocation, limiting customers to a percentage of their normal needs.

With use rates in the 90 to 100% range and tight to short supply situations, chemical producers are able to charge more—and in some cases, much more—for chemical products than they could just a year ago. Government figures show that in the second quarter, prices for chemicals and allied products were up about 10% from their year-earlier levels. And for industrial chemicals, prices were up about 9% from a year earlier.

Not reflected in the price data are discounts that were in place last year that have been eliminated this year and the fact that producers can expect to receive higher prices—in some cases double—for products shipped overseas than they would receive for products sold domestically.

The result is that chemical producers have been handed far greater earnings leverage than they have enjoyed in years. The high capacity use rates mean that chemical plants can operate much more efficiently. And producers can increase prices faster than their raw material costs are increasing. In fact, producers are starting to become concerned about price increases because they fear that customers may begin to switch back to competing materials such as metals or natural fibers as these materials become more cost competitive.

It looks, however, as if the good times are going to last for awhile. Gulf Coast sources say that July and August price increases have been substantial and generally are being accepted by their customers.

And just when it looks as if market demand may be slowing, something happens to pick it up again. For instance, U.S.-made automo-

FIRST-HALF 1988		12-MONTH RUNNING DATA			
Profit margin[b]		Change from 1987		Profit margin[b]	
1988	1987	Sales	Earnings	1988	1987
8.8%	7.7%	13%	31%	8.6%	7.4%
7.5	6.5	12	24	6.6	6.0
18.6	13.7	32	85	16.0	12.0
16.6	6.8	26	78	9.7	6.9
10.7	10.7	16	20	10.5	10.1
3.9	3.5	29	−10	3.6	5.2
5.1	5.0	4	16	5.2	4.7
6.1	5.0	11	43	5.6	4.3
13.9	8.7	26	103	12.0	7.5
11.3	11.6	17	12	11.1	11.6
9.6	7.4	14	97	7.4	4.3
3.2	3.7	12	19	4.0	3.8
17.3	8.7	43	200	17.0	8.1
8.1	3.2	11	98	5.8	3.3
3.5	2.3	28	589	3.7	0.7
6.4	8.0	3	−11	6.9	7.9
16.3	15.5	20	26	14.9	14.2
10.5	2.3	−10	1964	7.9	0.3
10.7	9.8	23	37	10.0	9.1
6.8	7.9	7	5	7.3	7.5
9.8	7.5	14	75	7.1	4.6
10.6	9.6	21	41	10.0	8.6
5.1	4.9	20	51	4.2	3.3
4.3	4.6	10	4	4.4	4.6
5.4	6.1	15	13	5.2	5.3
11.8	4.2	28	208	9.5	4.0
10.4	10.6	15	11	8.9	9.2
7.1	4.0	18	102	5.0	3.0
15.7	7.0	28	162	14.3	7.0
5.3	4.7	13	21	5.1	4.8
9.6%	**6.8%**	**18%**	**76%**	**7.9%**	**5.3%**
10.5%	**6.8%**	**19%**	**54%**	**10.6%**	**8.2%**
9.8%	**6.8%**	**18%**	**72%**	**8.3%**	**5.7%**

biles—one of the three major markets for chemical products—are finally beginning to take market share away from imported cars.

With this year's drought adding to the woes of farmers already deep in an agricultural recession, no one knows what will happen in this second major market.

But in the third—construction—the outlook seems to be brightening somewhat after a slowdown in the early part of the year. The National Association of Realtors' chief economist, John A. Tuccillo, says that the 8.4% May-to-June increase in sales of new single family homes indicates a robust housing market with significant demand remaining. Tuccillo cautions, however, "Although the demand is strong, it's not strong enough to sustain the June sale pace. We're expecting new home sales to drift downward for the rest of the year, especially as interest rates rise."

The increased demand and resultant earnings leverage provided earnings growth in the second quarter that was almost four times higher than sales growth. For the 30 chemical companies surveyed by C&EN, after-tax earnings from continuing operations increased 70% to an aggregate $2.07 billion on a sales increase of 18% to a total $20.1 billion. As a result, profit margins for the group rose to an average 10.3% in the second quarter from 7.2% in the same period in 1987.

In terms of earnings growth, the 15 larger firms on the list slightly outpaced the 15 smaller companies. The larger 15 had earnings growth of 71% to $1.77 billion, compared with growth of 65% to $301 million for the smaller companies. In sales, the top 15 scored a 21% increase to a total $17.3 billion against only a 7% sales rise for the smaller companies to a total of $2.84 billion.

However, the smaller companies led slightly in profitability. The average profit margin for this group was 10.6% in the second quarter compared with an average of 10.2% for the larger companies. In last year's second quarter, the group of larger companies had the better profit margin, at 7.2%, than the group of smaller companies, at 6.8%.

The results for the first half of this year show a trend similar to that for the second quarter. Overall, earnings for the 30 companies increased 70% from last year's first half to $3.82 billion on a sales increase of 19% to $39.2 billion. The average profit margin for the group rose to 9.8% from 6.8% in the same period last year.

For the half, the 15 larger companies had total earnings of $3.23 billion, up 71% from first-half 1987, and total sales of $33.6 billion, up 21%. The result was an average profit margin of 9.6%. The smaller companies showed an earnings increase of 69% to $592 million on a sales rise of 9% to $5.62 billion and an average profit margin of 10.5%. The profit margins for both groups in the first half of 1987 averaged 6.8%.

Petrochemicals largely stirred the earnings pot in the second quarter. At Arco Chemical, whose earnings increased 80%, president and chief executive officer Harold A. Sorgenti says, "Continued tight worldwide supply/demand conditions and a reduction in benzene feedstock costs enabled styrene margins to expand, significantly contributing to the gross profit increase versus the same period last year, despite a significant increase in ethylene feedstock costs."

Ground rules for C&EN earnings analysis

C&EN's quarterly report on financial performance of the U.S. chemical industry contains data from the 30 largest U.S. basic chemical companies and from 27 oil and diversified companies, each with more than $200 million in annual chemical sales.

To be included in the table of basic chemical producers, a company must have at least 50% of its sales in chemicals. That is why Du Pont, for example, is included in the table of diversified manufacturers.

In referring to chemical sales, C&EN means those chemicals whose molecular composition has been changed in the course of manufacture. Hence, chemical sales include those of traditional categories of basic petrochemicals and inorganics, organic intermediates and inorganic compounds, polymers such as plastics and fibers, agricultural chemicals, and specialty derivatives.

In listing earnings, the survey gives after-tax income for continuing operations before nonrecurring items and extraordinary charges. Foreign currency translations are included.

Pharmaceutical earnings advance in quarter

Like earnings for chemical companies and oil and diversified firms, earnings among major pharmaceutical producers generally rose in the second quarter. However, the growth in earnings was much slower than that for oil and gas companies and much less than that for the chemical companies, falling more in line with diversified firms that also produce chemicals.

For a group of 14 large pharmaceutical companies surveyed by C&EN, earnings for the quarter increased 17% to $1.76 billion on a sales increase of 12% to $13.5 billion. As a result, the average profit margin for this group was 13.0%, up from 12.6% in the second quarter of 1987.

For the first six months, earnings for the group totaled about $3.20 billion, a 16% increase from the first half of last year. Sales climbed 14% to $26.9 billion. And profitability increased slightly to 11.9% from 11.6% in last year's first half.

One of the big contributors to improved results in the quarter for many of the drug companies was increased foreign sales, and especially favorable currency translation factors. Also, companies benefited from a lower tax rate than was imposed upon them last year.

American Home Products says that net income benefited from a lower effective tax rate, which principally resulted from the reduction in the U.S. statutory rate. And Warner-Lambert says that net income per share for the quarter and the six months was favorably affected by the continued lower effective tax rate and by the company's stock repurchase program.

Baxter International says that it estimates that stronger foreign currency values contributed about $37 million to international sales for the quarter and $78 million for the half. Baxter's international sales for the quarter totaled $411 million; thus, foreign currency translations increased foreign sales almost 10% and total sales about 2% from what they would have been had the foreign exchange rates not improved.

At Bristol-Myers, chairman Richard L. Gelb says that domestic sales for the quarter increased 6%, whereas international sales improved 21%. The effect of exchange rate fluctuations increased total company sales less than 1% for the quarter and for the first six months, he says.

Favorable exchange rates aided sales growth at Squibb, contributing 4% for the quarter and 5% for the six-month period.

At Eli Lilly, chairman Richard D. Wood says: "Income grew faster than sales for a number of reasons, including lower manufacturing costs, higher interest income, and a lower corporate tax rate."

Some pharmaceutical companies say that they are generally on track for the year in terms of earnings improvement. At Squibb, chairman Richard M. Furlaud says: "The earnings for the quarter were on track with our earlier projections and we continue to expect growth in earnings per share for the full-year 1988 to be in excess of 25% despite the substantial increases in research and development expenses and in marketing support."

At a meeting of security analysts, Schering-Plough chairman Robert P. Luciano stated that the company's earnings per share for full-year 1988 should be about $3.45, up more than 20% from last year. He also expects, based on current trends, that earnings per share will improve another 20% next year.

Agricultural products helped some of the companies. Upjohn says that worldwide agricultural sales were up 14% from second-quarter 1987 with animal health products registering sharp gains in both foreign and domestic markets. At Lilly, worldwide sales of agricultural products increased, but only in the plant science area. Total sales of animal health products were down. And Pfizer says that its agricultural chemical sales were up 13% for the quarter.

	SECOND-QUARTER 1988						FIRST-HALF 1988					
	Sales	Earnings	Change from 1987		Profit margin		Sales	Earnings	Change from 1987		Profit margin	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
American Home Products	$1371.8	$215.9	12%	10%	15.7%	16.0%	$2764.4	$207.9	11%	−6%	7.5%	8.8%
Baxter International	1693.0	91.0	10	18	5.4	5.0	3328.0	182.0	11	27	5.5	4.8
Becton Dickinson	478.3	42.8	22	18	8.9	9.2	944.8	81.7	21	18	8.6	8.9
Bristol-Myers	1456.8	190.5	11	18	13.1	12.3	2976.8	218.6	12	13	7.3	7.2
Eli Lilly	1014.7	180.7	10	19	17.8	16.4	2086.8	413.9	10	17	19.8	18.7
Merck	1499.8	316.3	20	35	21.1	18.8	2936.6	587.0	24	35	20.0	18.5
Pfizer	1336.4	213.1	9	21	15.9	14.3	2634.3	432.9	12	18	16.4	15.7
Rorer Group	252.5	11.4	14	4	4.5	4.9	471.9	19.7	12	8	4.2	4.3
Schering-Plough	752.6	101.0	10	22	13.4	12.0	1505.1	202.5	10	21	13.5	12.2
SmithKline Beckman	1137.0	98.7	11	−25	8.7	12.9	2299.4	265.3	13	−5	11.5	13.7
Squibb	644.6	114.1	21	20	17.7	17.9	1241.5	205.0	24	25	16.5	16.4
A. H. Robins	202.6	8.0	11	3	3.9	4.2	428.7	22.1	9	−34	5.2	8.6
Upjohn	721.6	87.8	8	12	12.2	11.8	1384.0	183.2	10	15	13.2	12.6
Warner Lambert	951.3	91.6	13	27	9.6	8.5	1879.2	175.1	13	14	9.3	9.3

Oil, diversified manufacturers show improved results

	SECOND-QUARTER 1988						FIRST-HALF 1988					
	Sales	Earnings[a]	Change from 1987		Profit margin[b]		Sales	Earnings[a]	Change from 1987		Profit margin[b]	
	($ millions)		Sales	Earnings	1988	1987	($ millions)		Sales	Earnings	1988	1987
OIL AND GAS COMPANIES												
American Petrofina	$ 658.4	$ 49.0	8%	71%	7.4%	4.7%	$ 1,263.2	$ 79.4	10%	64%	6.3%	4.2%
Amoco	2,215.0	531.0	2	71	24.0	14.4	4,205.0	1000.0	4	75	23.8	14.2
Ashland	2,087.5	56.9	16	42	2.7	2.2	4,009.4	77.5	18	91	1.9	1.2
Atlantic Richfield	4,576.0	375.0	11	14	8.2	8.0	9,184.0	776.0	16	36	8.4	7.2
Chevron	7,300.0	343.0	0	60	4.7	2.9	14,800.0	805.0	5	53	5.4	3.7
Exxon	21,626.0	1200.0	7	4	5.5	5.7	43,634.0	2655.0	10	20	6.1	5.6
Kerr-McGee	729.9	35.9	0	32	4.9	3.8	1,393.7	46.1	9	−3	3.3	3.7
Mobil	14,214.0	452.0	16	59	3.2	2.3	28,114.0	957.0	17	81	3.4	2.2
Occidental Petroleum	4,744.0	87.0	10	def	1.8	def	9,220.0	145.0	9	def	1.6	def
Phillips Petroleum	2,881.0	170.0	9	5567	5.9	0.1	5,780.0	300.0	12	def	5.2	def
Shell Oil	5,427.0	263.0	5	−1	4.8	5.1	10,478.0	609.0	8	63	5.8	3.9
Sun Co.	2,430.0	96.0	0	7	4.0	3.7	4,820.0	156.0	3	22	3.2	2.7
Texaco	9,400.0	207.0	11	60	2.2	1.5	18,100.0	383.0	6	55	2.1	1.5
Unocal	2,553.0	64.0	6	3	2.5	2.6	4,851.0	108.0	8	−12	2.2	2.7
DIVERSIFIED MANUFACTURERS												
Allied-Signal	3,129.0	128.0	10	15	4.1	3.9	6,071.0	240.0	11	13	4.0	3.9
Borden	1,783.7	73.7	11	18	4.1	3.9	3,386.1	126.1	12	18	3.7	3.5
Du Pont	8,500.0	639.0	9	27	7.5	6.5	16,500.0	1229.0	11	37	7.4	6.0
Eastman Kodak	4,134.0	390.0	29	8	9.4	11.3	7,462.0	650.0	27	20	8.7	9.2
Engelhard	529.8	14.1	−12	−22	2.7	3.0	1,041.2	27.5	−9	−13	2.6	2.8
FMC	892.7	37.8	8	−24	4.2	6.0	1,606.6	62.0	3	−17	3.9	4.8
Ferro Corp.	259.3	11.9	19	65	4.6	3.3	500.5	23.1	18	65	4.6	3.3
GAF	266.8	35.4	25	19	13.3	13.9	483.3	57.2	19	14	11.8	12.4
3M	2,711.0	309.0	14	29	11.4	10.1	5,313.0	586.0	16	29	11.0	9.9
Morton-Thiokol	623.2	38.0	12	5	6.1	6.5	1,227.7	79.5	14	9	6.5	6.7
NL Industries	393.8	38.6	13	676	9.8	1.4	767.4	70.2	17	def	9.1	def
PPG Industries	1,451.0	133.8	9	31	9.2	7.7	2,824.0	252.4	9	33	8.9	7.3
Vulcan Materials	284.5	46.0	20	21	16.2	15.9	487.2	61.6	20	27	12.6	11.9

a After-tax earnings from continuing operations excluding significant nonrecurring and extraordinary items. b After-tax earnings as a percentage of sales. def = deficit.

Quantum Chemical chairman and chief executive officer John Hoyt Stookey attributed the company's 33% sales increase and 287% jump in earnings to continued strong demand with generally higher selling prices and improved profit margins for petrochemicals.

And Aristech's chairman and chief executive officer Thomas Marshall attributed a 17% sales growth and 119% profit growth in the second quarter to high operating levels and continued market strength, both domestic and export, for the company's product lines, especially phenol and related products, and polypropylene resins.

The contribution of petrochemicals to the bottom line is especially evident at the oil companies. Amoco's chemical operations had earnings of $189 million in the quarter, up 81% from last year. The company says that olefins earnings were at record levels as margins expanded in the tight, capacity-limited market. Sales volumes and margins continued very strong for polymer and chemical products, reflecting continuing robust worldwide demand, the company says.

Texaco posted a 132% increase in chemical earnings to $44 million in the quarter, reflecting higher margins from improved operating efficiencies and higher sales prices, particularly in the olefins business, the company indicates.

Shell Oil showed only a 32% increase in second-quarter chemical earnings to $133 million, but it had a limiting factor—the shutdown of its ethylene cracker. President Frank H. Richardson says, "The improvements in both 1988 periods resulted primarily from higher margins in commodity chemicals and polymers. The explosion at Norco impaired second-quarter chemical earnings, primarily because of its impact on ethylene production."

However, those higher prices that petrochemical companies were receiving translated into higher raw material costs for other chemical firms. At Rohm & Haas, chairman J. Lawrence Wilson says that "profit margins were maintained as the combined effects of higher production volume, good plant operations, and higher selling prices overcame the negative impact of sharply higher feedstock costs."

Hercules, Witco, and Lubrizol also noted higher raw materials costs. ☐

Chemists Still Being Fired Despite Good Times for Industry

Michael Heylin, C&EN Washington

Better market conditions and the corporate restructuring and streamlining efforts of recent years have combined to sharply revive the financial fortunes of chemical and related industries over the past several quarters. But these improvements have not been universal and major staff reductions affecting chemical professionals are still happening.

The latest report by ACS's Committee on Professional Relations (CPR) examines eight such mass terminations that occurred between February 1986 and April 1988. These cutbacks involved about 200 chemists and chemical engineers. Several of these reductions included many terminees who took either voluntary or involuntary early retirement. The eight firms involved reported mixed earnings performances in 1987, with about as many increases as declines compared with 1986.

The largest mass termination affected 53 chemical professionals at General Foods. It included 40 voluntary retirements. At Allied-Signal, 14 of 19 involuntary terminees were eligible for normal or early retirement benefits. And many of the 35 chemical professionals caught in an involuntary companywide staff reduction by Phillips Petroleum were eligible for an early retirement program.

According to CPR, the other five terminations covered in the report involved about 40 chemical professionals at Dartco, about 20 at Domino Amjet, 19 at Colgate-Palmolive, 17 at Akzo America, and seven at Gencorp. The terminations at Gencorp and Colgate-Palmolive were both due to "restructurings," in Gencorp's case triggered by a hostile takeover attempt.

Chemical professionals involved in these eight terminations generally fared better than did colleagues involved in earlier mass terminations. However, CPR is concerned about the increasing use of restrictive termination agreements that terminees must sign to receive maximum separation benefits. These agreements severely restrict the activities of ex-employees. Such agreements limit the ability of terminees to bring suit against their former employers. In some instances, they also restrict terminees' freedom to reveal severance conditions.

This latest CPR report is the 27th in a series dating back to 1974. They all compare the performance of em-

Employer compliance with ACS guidelines

These employers provided information	Approximate number of employees separated	Advance notice	Severance pay	Assistance	Pension vesting	Employee service	Protection plans
Allied-Signal, Buffalo Research Laboratory (Buffalo, N.Y.)	19	☐	▨	☐	☐	■	▨
Colgate-Palmolive, Research Center (Piscataway, N.J.)	19	■	☐	☐	☐	☐	☐
Gencorp, Research Division (Akron, Ohio)	7	■	▨	☐	☐	■	☐
General Foods, Technical Center (Tarrytown, N.Y.)	53	☐	☐	☐	☐	■	☐
Phillips Petroleum (Bartlesville, Okla.)	35	▨	☐	☐	☐	▨	☐
These employers provided no information; hence, all ratings based on terminee responses							
Akzo America, Stauffer Chemical (Dobbs Ferry, N.Y.)	17	☐	☐	☐	☐	■	▨
Dartco Mfg., Division of Premark International (Augusta, Ga.)	40	■	▨	☐	☐	■	▨
Domino Amjet (Waukegan, Ill.)	20	■	☐	■	*	☐	☐

* No information from any source.

☐ Employer met or exceeded guideline standard.

▨ Two or more individuals below guideline standard, but average experience better than "substantially below" criterion.

■ Employer was substantially below guideline standard, which is defined as follows:

- Advance notice—less than two weeks.
- Assistance—no assistance rendered.
- Severance pay—less than one week per year of service.
- Employee service—more than 40% of terminees had 10 or more years of service.
- Protection plans—no continuation of protection plans

ployers terminating chemical professionals against standards contained in ACS's Professional Employment Guidelines (PEG). CPR defines a mass termination as a situation in which the employment of three or more chemical professionals is terminated within a six-month period for reasons other than continuation of previously documented inadequate performance, completion of a contract, or cause. All terminees do not have to have worked at the same location.

The latest report makes comparisons against six standards. These are concerned with advance notice, severance pay, assistance in finding new employment, pension vesting, length of employee service, and protection plans. Earlier reports also included a standard on rehire privileges. An employer was deemed to comply if it explained its rehire policy to terminees, regardless of what the policy was. CPR now feels that this is not consistent with the original intent of encouraging the preferential rehiring of terminees.

In the more than 230 mass terminations examined in the 26 previous reports, employers complied with the six standards covered in the latest report an average of 48% of the time. In the latest report compliance was at a relatively high 62%. This apparently reflects the generally more generous treatment afforded those taking early retirement or qualifying for special severance packages—the golden, or at least bronze, parachute syndrome.

ACS guidelines

Advance notice. Four-week minimum.

Severance pay. Minimum is two weeks per year of service. Additional notice may be given, by mutual agreement, in lieu of severance pay.

Assistance. Efforts should be made to place terminee in another position within the organization, or terminee should be given assistance to find employment elsewhere.

Pension plan vesting. Full vesting after 10 years' service.

Employee service. Those with minimum of 10 years' service should not be terminated except for continued evidence of previously documented inadequate performance or cause.

Employee protection plans. Should be extended for a minimum of one month, plus two weeks for each year of employee service, following termination, at same rate of contribution as before. Employee would have additional 31-day grace period.

In examining terminations, CPR seeks information from both employers and terminees. Traditionally about two thirds of employers have provided data, including five of eight in the latest report. For this report CPR also received help from the New York, Northeast Oklahoma, and Western New York local sections of ACS in obtaining data directly from terminees. Such information tends to be spotty. In some cases it comes from a very small percentage of terminees.

CPR encourages individual ACS members to send information on terminations of which they have personal knowledge to American Chemical Society, Office of Professional Relations, 1155—16th St., N.W., Washington, D.C. 20036. The committee will provide, on request, copies of its termination reports as well as a summary list.

CPR is currently examining three more mass terminations that occurred between January and March 1988. They were at Battelle Memorial Institute, Westinghouse-Hanford, and PPG Industries.

The PEG guideline for severance pay calls for a minimum of two weeks' pay for each year of service. In the previous 26 reports it was complied with only 19% of the time. In the latest report five employers fully complied. The other three met the standard for most, but not all, of their terminees.

However, the severance agreements that are of concern to CPR were prevalent in this latest batch of mass terminations. Terminees at Allied-Signal, Colgate-Palmolive, Dartco, and General Foods were required to sign termination agreements that contained conditions for severance and/or a release from any other claims. Colgate offered two severance packages. The higher package was contingent on the terminee's promise not to sue the company for any grievances arising from employment or termination. At Dartco, all terminees who supplied information to CPR reported signing a special release of all claims in exchange for an additional 13 weeks of severance pay.

Another PEG standard that has been complied with poorly is the one concerning employee service. It states that those with a minimum of 10 years of service should not be terminated except for continuation of already documented inadequate performance or cause. For the previous 26 reports the standard was complied with only 22% of the time. And for the nine reports since 1984 compliance has dropped to only 9%. This apparently reflects the widespread use of early retirement programs. In the latest report, two of the eight employers complied. In the termination at Allied-Signal, 16 of the 19 terminees had 10 or more years of service, as did 30 of the 53 terminees at General Foods.

The guideline for advance notice calls for a minimum of four weeks. In the latest report, three of the eight employers complied. This was in line with the 39% compliance rate for the previous 26 reports.

Employee protection plans should be extended for a minimum of one month plus two weeks for each year of service, according to PEG. This guideline has been complied with about half the time. In the latest report, five of the eight employers met or exceeded this standard.

Employers have generally done better in meeting the PEG guideline for assisting terminees in finding new employment. Overall, compliance has been at the 70% level. In the latest report, seven of the employers complied. For the other, Domino Amjet, two terminees reported receiving no assistance.

The PEG pension-vesting standard of full vesting after 10 years of service is almost always met. In the latest report, seven of the eight employers complied. For the other, Domino Amjet, there was insufficient information for CPR to make a judgment. For the past six years compliance with the standard has been at the 94% level. For all 27 reports, it is 86%. □

NOTE

ONLY THE FOLLOWING PAGES OF THIS

PUBLICATION HAVE BEEN FILMED

Cov. 1, Pgs. 1, 2, 13-15,

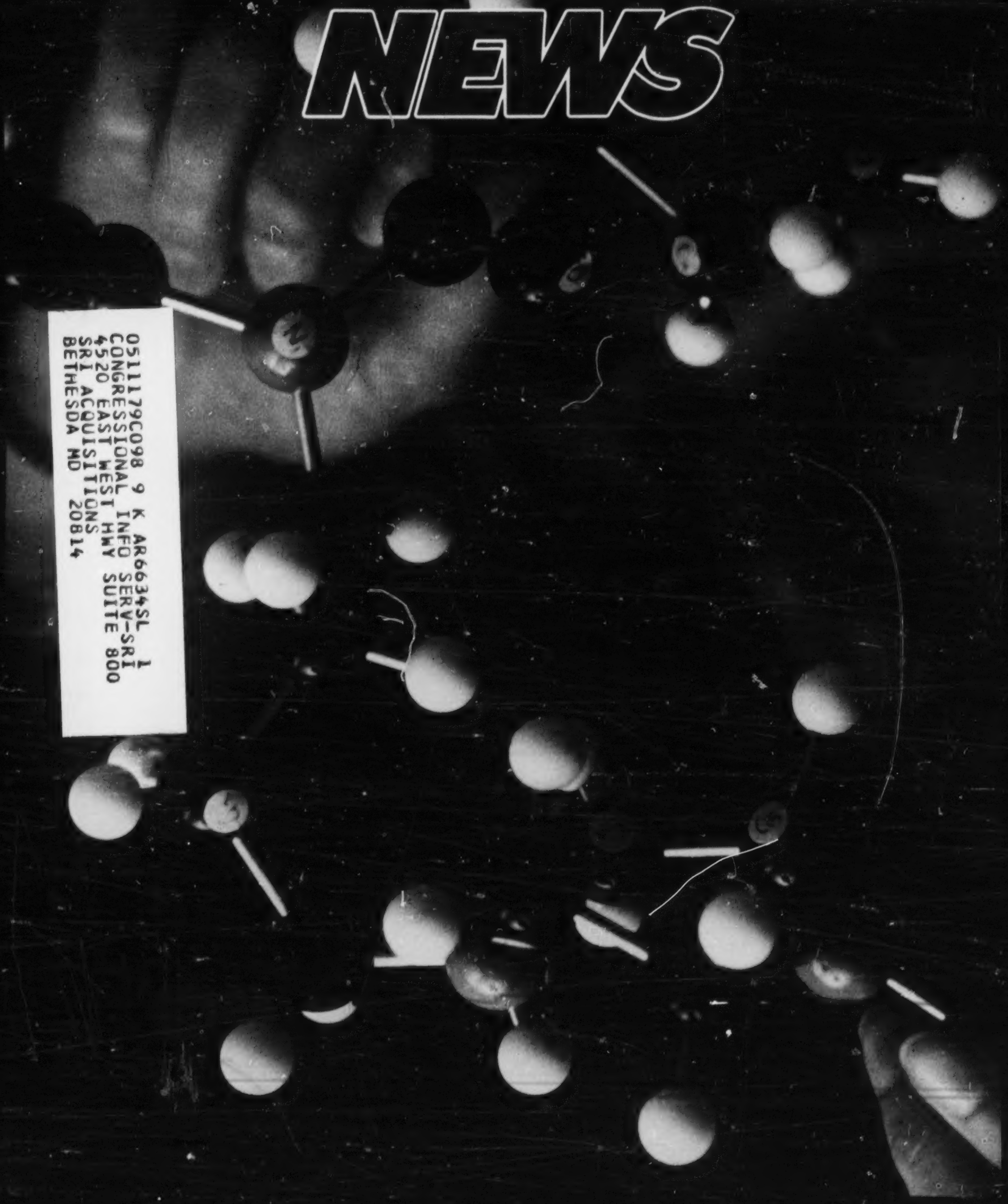
29-40, 42-46, 48, 51, 52,

54, 58-64

A1250-1
8/25/88

AUGUST 22, 1988

CHEMICAL & ENGINEERING NEWS



0511179C098 9 K AR6634SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 34
CENEAR 66 (34) 1–92
ISSN 0009-2347

AUGUST 22, 1988

News of the Week

- **Cabot Corp. has adopted an antitakeover plan to deter possible acquisition by GAF and its feisty chairman, Samuel Heyman.** Page 4
- **Synthetic enzymes that catalyze cleavage of target RNA molecules with high specificity have been developed by an Australian research team.** Page 5
- **New report from a National Research Council panel states that better safety planning is needed in the Department of Energy's research reactor program.** Page 5
- **Increased awareness and cooperation are needed to protect space missions from collisions with orbiting debris, say international space officials.** Page 6
- **Discovery that atmospheric levels of two bromine-containing halocarbons are on the rise has intensified concerns about the ozone-destroying potential of these compounds.** Page 6

Business

Du Pont, Akzo have ended their long-running dispute over aramid fiber patents, are now focusing on building markets for the fibers. **Page 10**

Canadian chemical companies continue on a high, chalking up record earnings in the second quarter. **Page 13**

Government

EPA has proposed four alternative approaches for regulating benzene emissions and is seeking public comment on how to proceed. **Page 22**

Sierra Club report recommends that U.S. energy policies place increased reliance on conservation and renewable energy sources. **Page 23**

Education

NSF official calls for commitment to improve the quality of U.S. science and engineering education, suggests need to head off predicted shortfalls in scientific manpower levels. **Page 26**

National Research Council report discusses how to organize personnel databases on engineers to improve the information's usefulness. **Page 27**

Books

"The Academic's Handbook," edited by A. Leigh DeNeef et al gives two viewpoints of the academic game. **Page 65**

ACS News

Council will act on three petitions—open meetings, emeritus status, and membership count for divisions—at its meeting in Los Angeles. **Page 69**

Special Report

C&EN's annual compilation of data on research and development reveals that U.S. chemical R&D is healthy and growing, with overall spending on R&D expected to reach $128 billion this year, up 7% over 1987. **Page 29**

Cover: Photo courtesy of Bristol-Myers Co.

Letters 2

Concentrates

Business 7

Government 16

Science/Technology 25

The Departments

New Products 74

Meetings 77

Newscripts 92

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist), Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Cynthia G. Smith

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Cram, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 91)

LETTERS

Nonleaded gasoline

SIR: I would like to propose to all of our oil companies as well as the American Petroleum Institute, plus others, that the designation of unleaded gasoline on gasoline pumps at gasoline stations be changed to nonleaded gasoline.

The term unleaded is misleading. In teaching large classes of nonscience majors on the subject of energy and the story of gasoline, I always go 'round and 'round with my students, trying to explain that the lead in unleaded gasoline has not been removed from the gasoline—it was never added. We of course know, for example, that toluene and benzene are additives in unleaded gasoline to ensure smooth combustion.

Therefore, I strongly urge the use of the term nonleaded to replace unleaded. This will be a great favor to the general public. **Saul Barron**

Emeritus Professor of Chemistry
State University of New York, Buffalo

Bond energy distinction

SIR: The brief account of the recent work of Emily Carter and William Goddard (C&EN, June 27, page 26) emphasizes the necessity of distinguishing carefully between "bond dissociation energy (BDE)" and "contributing bond energy (CBE)" when describing bond strength. The authors correctly identify their $\mathrm{C{=}C}$ bond energy as "D" (BDE) in their paper on C_2F_4. The C&EN item does not specify which kind, and one can only infer this from the mention of experimental determinations, which would here be impossible for CBEs.

Calculation of the contributing bond energies by the theory of polar covalence gives 105.4 kcal for the $\mathrm{C{-}F}$ bond and 154.5 kcal for the $\mathrm{C{=}C}$ bond, totaling 576.3 for the atomization energy of C_2F_4, the experimental value being 576.1. The $\mathrm{C{=}C}$ bond is not really "one of the weakest known." On the contrary, it is about 10 kcal stronger than the average $\mathrm{C{=}C}$ bond in alkenes, consistent with its shorter bond, 127 instead of 134 picometers. The reason it comes apart so easily is that when two CF_2 radicals are liberated from the double bond, their reorganization strengthens the $\mathrm{C{-}F}$ bonds. The energy released by this strengthening contributes to the dissociation of the C_2F_4, reducing the net requirement. It is not always possible to understand radical reorganizational energy, but here a reasonable explanation exists. Subtracting the authors' BDE of 64.5 kcal from the calculated contributing energy of 154.5 gives 90 kcal, which divided among the four $\mathrm{C{-}F}$ bonds adds 22.5 kcal to the energy of each. This is approximately the difference between the energy of a $\mathrm{C{-}F}$ bond calculated for complete lone pair bond weakening in the fluorine and that calculated for half-removal of the lone pair bond weakening in the fluorine. Thus the double bond in C_2F_4 is much easier to break than otherwise expected, possibly because the liberation of two half-filled orbitals per carbon atom somehow permits reduction of the lone pair bond weakening effect (LPBWE) on the homonuclear bond energy of the fluorine atoms. Additional understanding of LPBWE will be required for evaluating this suggestion. In fact, however, the authors' standard heat of formation of the CF_2 radical, −46.5 kcal, corresponds to a $\mathrm{C{-}F}$ bond energy therein of 127.8 kcal per mole of bonds, which is 22.4 kcal greater than in C_2F_4.

A BDE is the same as the CBE only for diatomic molecules. Otherwise it represents the sum of the CBE and the reorganizational energy of the liberated radical(s). **R. T. Sanderson**

Fort Collins, Colo.

Periodic table long form

SIR: Joseph Lound-Keast (C&EN, Feb. 22, page 2) criticizes the choice of a numbering system of 1–18 of columns of the long form periodic table by the International Union of Pure & Applied Chemistry commission on inorganic chemistry [*Chem. Int.* **7**, 26 (1985); Busch, D. H., *Ibid.*, **9**, 49 (1987)]. He says, in part, that "it perpetuates the misconception of so many in the chemical profession, that, in some way, the periodic table has only 18 groups and two 'footnotes' of 14 elements that have to be 'squeezed' into the box alongside actinium and lanthanum."

In my opinion, assigning group numbers of 1–18, in addition to deprecating the 28 elements in the footnotes, suffers from a lack of significance of the numbers. Lound-Keast makes a very useful suggestion to remedy this: "The groups could be numbered according to the valence subshell; for example, the carbon group becomes the p2 group, the alkaline earths the s2 group . . . providing at first glance information about position and electronic structure" (after all, this is one major purpose of the periodic table). He goes on to advocate a "true" long form without footnotes.

In a paper published in the *Journal of* pulled and laid into position. Akzo's Oostindiër thinks there is no engineering reason why a bridge could not span the English Channel instead of a tunnel and that the bridge cables might be made of para-aramid fibers. Du Pont also has promoted the fiber as a lightweight replacement for the toe in what are now steel-toed shoes, and in shoe soles for puncture proofing. It is pushing the fiber as a reinforcement in the heel and toe of socks to aid their durability.

Du Pont is also promoting the use of its meta-aramid Nomex fiber in combination with Kevlar. Kevlar adds dimensional stability and tear resistance whereas Nomex adds high-temperature resistance. The combination of the two fibers is useful in firemen's turnout coats and in airline seat covers. Du Pont has advanced to the point where the familiar yellow Kevlar may now be dyed. Green and black producer-colored Kevlar is now in the testing stage, says Du Pont's Neal.

"The Man in the White Suit" thus may now dress in yellow, green, or black. And perhaps Emgo U.S.A., the apparel company that attempted to offer the fashion-conscious urban guerrilla designer Kevlar clothes in 1982, may try it once again with some color. □

Canadian chemical profits continue to surge

At the year's halfway point, the Canadian chemical industry shows no signs that it is about to slow down. Strong demand and rising prices are helping Canadian chemical companies to chalk up record earnings.

Du Pont Canada, the largest of the three big publicly held chemical firms in Canada, says that its second-quarter results exceeded the record performance that it set in the first quarter. Union Carbide Canada's second-quarter earnings are double what they were in the same period last year. And a continued strong performance in the second quarter produced for Celanese Canada the highest quarterly net income in the company's history, as well as record-breaking first-half earnings.

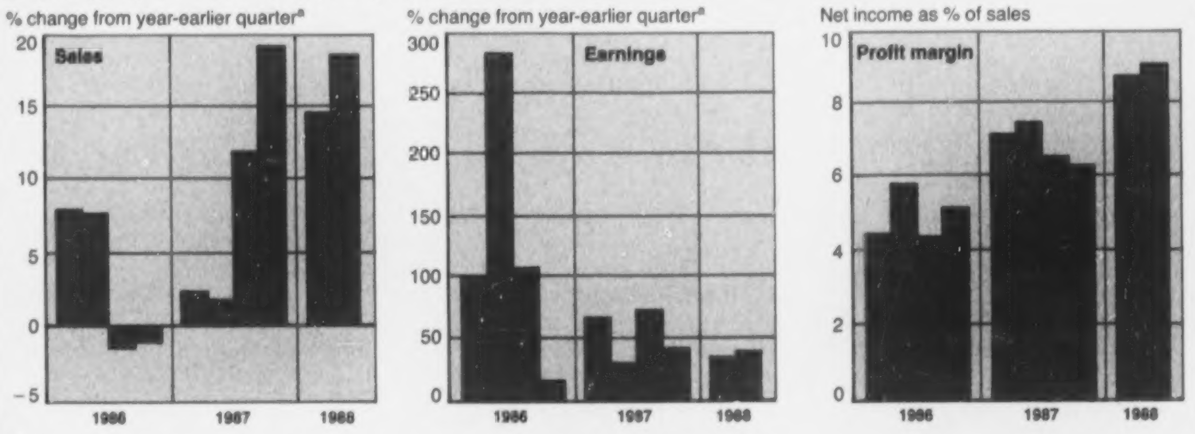
Throughout most of the Canadian chemical industry, the story is the same. Strong domestic demand, a hefty export market, and higher prices are combining to embellish the bottom lines of most Canadian chemical companies.

Chemical shipments in the first quarter ran 6% ahead of last year. But through the first four months of the year, chemical exports were a solid 25% higher than they were a year earlier. Exports of organic chemicals as well as synthetic rubber and plastics were a whopping 35% ahead of last year's pace. Even fertilizer exports, which have been lethargic for the past few years, were up 28% over the first four months of 1987.

The consequences of this surge are apparent in the first-half financial reports of Canadian chemical companies. For instance, the combined second-quarter sales of the three publicly traded Canadian chemical companies tracked by C&EN were $516 million (U.S. dollars; $1.00 = 1.230 Canadian dollars on June 30), up almost 19% on a Canadian dollar basis. Earnings were up an even stronger 42.8%. These companies include Celanese Canada, Du Pont Canada, and Union Carbide Canada. Earlier this year, the fourth publicly traded Canadian chemical company usually tracked by C&EN, C-I-L Inc., became a wholly owned subsidiary of ICI and stopped reporting quarterly earnings.

For the first six months, the combined sales of the three companies were $963 million, 16.7% higher than last year's first half. And net income increased an even stronger 41%.

Union Carbide Canada apparently has adapted well to its recent restructuring. Second-quarter net income was $9.2 million, up a staggering 102% over last year's similar period. Sales improved 46% to $120 million, and even after a change in accounting consolidation that the company adopted this year, growth in comparable sales was still ahead


Earnings growth continues to outpace sales growth

Note: Combined results of Celanese Canada, Du Pont Canada, and Union Carbide Canada. a Based on Canadian currency.

23%. Company chairman W. Norman Kissick says the increase "largely reflects higher selling prices in a current tight market."

For the first half, Union Carbide Canada's net income was $15.7 million, up 66% on sales ($223 million) that were ahead only 42% of the year-earlier period. Kissick notes that Pétromont, the Montreal-based producer of primary petrochemicals that Union Carbide Canada owns jointly with Société Générale de Financement du Québec, continued to be a major contributor to the improvement in Carbide's profits. In addition, the company's carbon products and its industrial, medical, and specialty gases chalked up significant gains.

Meanwhile, Celanese Canada is basking in its record second-quarter and first-half performances. Net income for the second quarter rose 79% to $10.2 million on a 19% sales increase to $84.9 million. For the first half, the company's net income gained 88% to $19.5 million, and its sales rose just under 20% to $161 million.

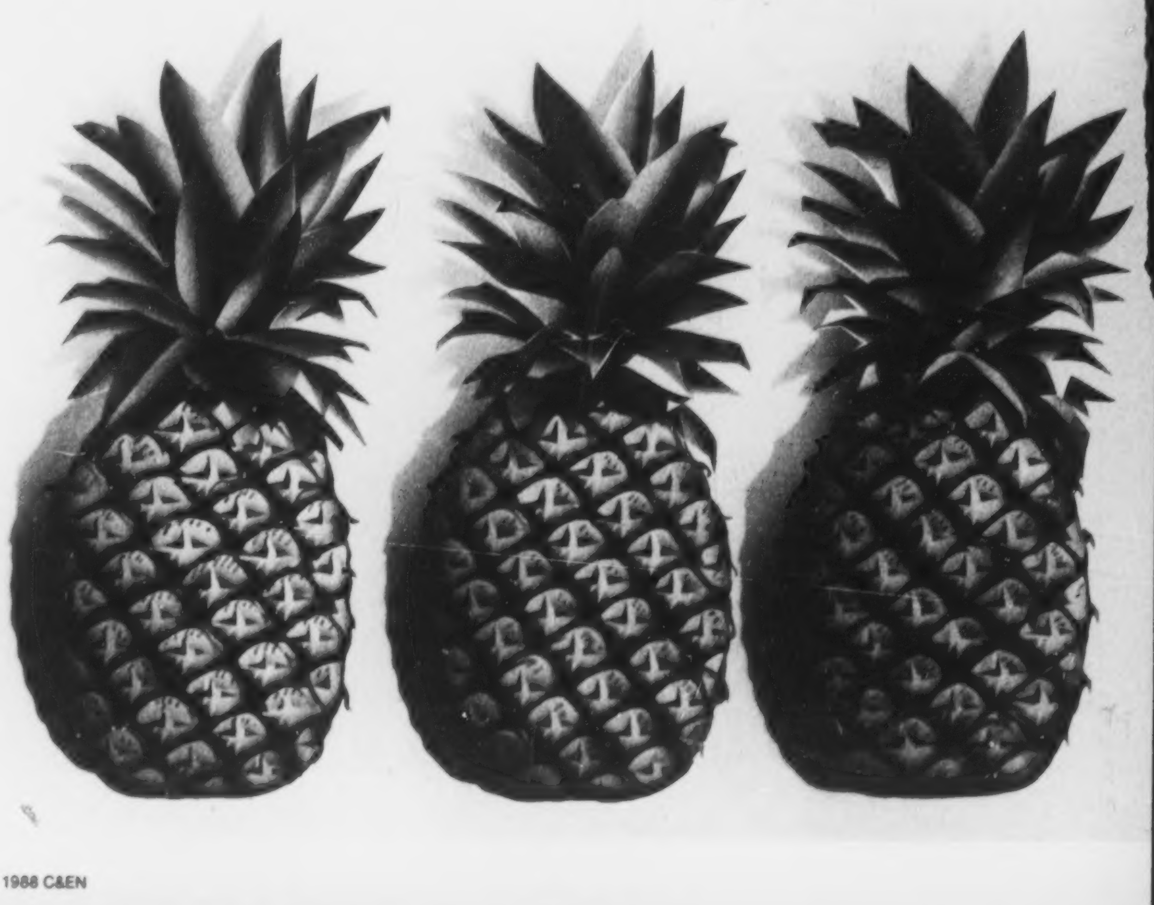
All of Celanese Canada's operating groups are contributing to the company's record-breaking year so far. In the textiles group, both the polyester staple fiber and heavy industrial fiber units are operating at capacity, although company president Paul H. Williams warns that substantial increases in raw materials prices are putting pressure on these businesses.

The cellulosic fiber unit also is operating at effective capacity. High-

Canadian chemical companies are enjoying a strong year

$ Millions[a]	Net sales	Change from 1987[b]	Net income[c]	Change from 1987[b]	Profit margin[d] 1988	Profit margin[d] 1987
			SECOND-QUARTER 1988			
Celanese Canada	$ 84.9	19.3%	$10.2	78.6%	12.0%	8.0%
Du Pont Canada	311.1	10.6	27.3	21.7	8.8	8.0
Union Carbide Canada	119.7	45.9	9.2	101.8	7.7	5.6
TOTAL	**$515.7**	**18.7%**	**$46.7**	**42.8%**	**9.1%**	**7.5%**
			FIRST-HALF 1988			
Celanese Canada	$161.2	19.6%	$19.5	88.4%	12.1%	7.7%
Du Pont Canada	579.2	8.6	50.6	23.4	8.7	7.7
Union Carbide Canada	222.5	41.6	15.7	66.1	7.1	6.0
TOTAL	**$962.9**	**16.7%**	**$85.8**	**41.1%**	**8.9%**	**7.4%**

a $1.00 = $1.230 Canadian (second quarter) and $1.249 Canadian (first half). b Based on Canadian currency. c Based on continuous operations and excluding extraordinary items. d Net income as percentage of sales.



er shipments and improved margins on exports are offsetting a softer domestic market, says Williams. In industrial products, cellulose acetate tow, which is used for cigarette filters, continues to be sold out, even though the company increased capacity during the second quarter.

Among chemicals, Celanese Canada finally benefited from a strong demand for methanol. As a result, the company was able to boost prices on the alcohol. Williams says that the balance of the company's chemical business was a "major contributor" to the company's profit picture, even though many products were hit with feedstock price increases.

Another record-setter in the Canadian chemical industry was Du Pont Canada. In the second quarter, net earnings were a record $27.3 million, 22% more than in the last year's second quarter. For the first half, earnings from operations hit $50.6 million, up 23% over last year's first half. Du Pont Canada was hurt by lower earnings from its carpet fiber business, but that was more than offset by higher sales volume and selling prices in other product lines.

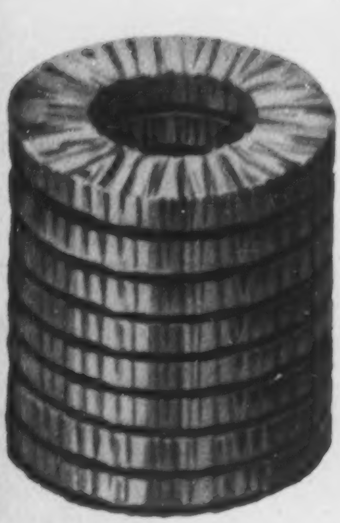
Du Pont's sales were up 11% in the second quarter to $311 million and up 8.6% in the first half to $579 million. Sales of carpet fibers were down from last year's record levels and the company lost the revenue it used to receive from its explosives business that it sold in January. But Du Pont Canada's president J. Edward Newall says that sales of most other products were higher. Among the leading gainers: plastic resins, specialty packaging films, herbicides, automotive finishes, and hydrogen peroxide.

Can Canadian chemical companies continue the torrid pace that they have set so far this year? Many top executives in the industry think so. Du Pont Canada's Newall says that the outlook for the rest of the year looks good. Carbide Canada's Kissick thinks that the company's "positive performance trend" will continue for the rest of the year. And Celanese Canada's Williams believes that the outlook for the remainder of 1988 remains encouraging.

However, Williams hints at one possible trouble spot. He says that if the Canadian dollar continues to strengthen, it could hurt his company's export selling prices.

No doubt it could have an impact on the all-important exports of other Canadian chemical companies as well. In June, the Canadian dollar was worth 83.2 U.S. cents. In January 1986, it was worth only 70 U.S. cents. Recently, it has weakened to about 82 U.S. cents and many Canadian economists think that the rise in the Canadian dollar is over. If not, Canadian chemical exports—and Canadian chemical companies—could be in trouble.

Earl Anderson



The difference between our hydrazine and everyone else's.

Purity. ATOCHEM hydrazine hydrate leaves out contaminants you'd rather do without. In fact, unwanted extras like sodium chloride and heavy metals are virtually non-existent in the hydrazine you get from us. Which means our hydrazine could cause fewer problems in your process and help you achieve higher yields.

No one else can match our purity because no one else uses our patented production process. We substitute peroxide compounds for sodium hypochlorite. And since we don't start with sodium, we don't end up with salt by-products.

We don't give you lots of impurities in our hydrazine, but we *do* give you more of what you're looking for in a supplier. Like technical service—no one knows hydrazine better than we do. And fast delivery—we'll ship within 24 hours from one of our six warehouses throughout the U.S., in a range of packaging options from small drums to bulk shipments.

Get more of what you're paying for. Specify hydrazine from ATOCHEM.

Contact Olivier Meurzec, Marketing Manager, ATOCHEM INC., Chemical Division, P.O. Box 607, Glen Rock, NJ 07452.

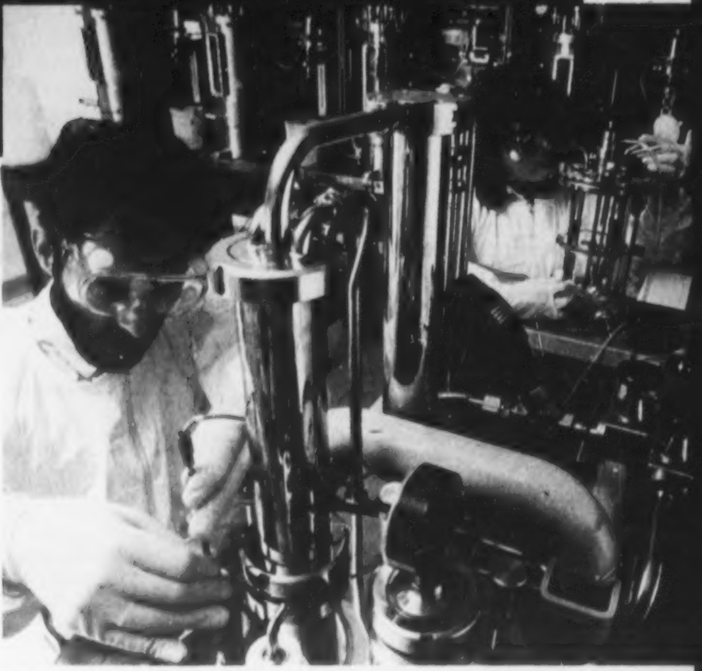
For immediate help, call us Toll Free at 1-800-932-0420. In NJ: (201) 652-8575.

ATOCHEM INC.
elf aquitaine group ATO

CIRCLE 5 ON READER SERVICE CARD

Eli Lilly & Co. photo

Facts & Figures for Chemical R&D



Bristol-Myers Co. photo

Rebecca L. Rawls, C&EN Washington

1 Overview
Where funds come from for R&D and where they go. Who makes up the scientific labor force. Who gets U.S. patents 32

2 Federal Government
How much federal agencies spend and what they spend it on, particularly in the fields of chemistry and physical sciences 38

3 Industry
How much the chemical industry spends on R&D and how the funds are spent. Where chemical jobs are. Which ones pay best 46

4 Universities & Colleges
Who funds academic R&D and which schools do the most. Trends in capital spending, equipment purchases, and degrees awarded 58

R&D effort to reach $128 billion in 1988

Research and development in the U.S. is healthy and growing. Overall spending on R&D is expected to reach $128 billion this year, up 7% over last year. With inflation low—projected to be 3 to 4% for the year as a whole—R&D spending will rise at least 3% in 1988 in real terms.

That rate of expansion is about the same as last year's and considerably better than the meager 1% growth, after taking inflation into account, that R&D experienced in 1986. Though not up to the headier levels experienced earlier in the decade, when inflation-adjusted growth climbed as high as 8% per year, current levels nevertheless indicate genuine expansion of the country's R&D effort. Taken altogether, R&D spending over the past decade has been growing, in real terms, at a respectable 5% per year. During the 1970s, in contrast, the rate of growth was a mere 1% annually.

Jobs, too, in science and engineering are growing at a healthy rate. Data on employment lag a bit behind those dealing with spending, but in 1986 4.6 million men and women were working in science and engineering in the U.S., twice as many as in 1976. That represents a growth in jobs in these fields of 7% per year during the decade, a period when total civilian employment, by comparison, increased just 2% a year.

R&D also is doing well in relation to the rest of the U.S. economy. R&D spending in 1988 will represent about 2.6% of gross national product, a percentage that's been holding steady since 1985. A decade ago R&D was getting only 2.1% of GNP. And the share of GNP that is going into R&D has not been higher since 1969.

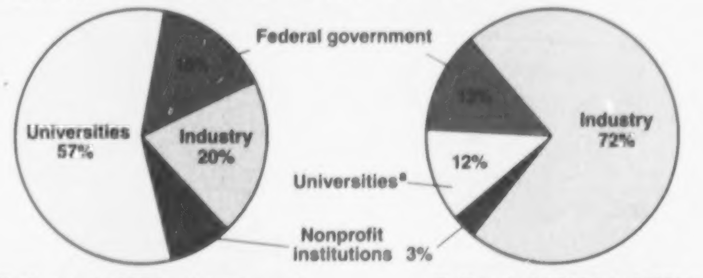
By any of several indicators, then, the R&D effort in the U.S. is steaming along pretty well. How it's faring in comparison with the R&D efforts of other countries is another question, and one for which figures are harder to come by. At a time of rapidly changing technology and increasingly stiffer global economic competition, concern for the ability of the U.S. to maintain a worldwide technological edge has never been greater.

Several countries that come to mind as potential competitors with the U.S. in high-technology markets spend as much or more of their GNP on R&D than the U.S. does. West Germany, for instance, has been steadily increasing the share of its GNP that supports R&D for the past decade, very much as the U.S. has, and spent an estimated 2.7% of its GNP on R&D in 1986, the latest year for which figures are available. Japan spent 2.8% of its GNP on R&D in 1985, the most recent year for which data are available for it.

In addition, because military budgets are relatively small in both West Germany and Japan, practically all their spending is for civilian R&D. In the U.S., on the other hand, defense-related R&D now accounts for a third of total outlays, up from only about 22% in 1980 to the highest level since 1970. Of total U.S. R&D spending, 63% is either nonfederal in origin or is for civilian-related work supported by the government, down from about 70% in the late 1970s and early 1980s. Consequently, civilian-related R&D's share of U.S. GNP is just 1.7%, well below that in either Japan or West Germany.

A look at patent activity suggests that both Japan and West Germany are significant competitors with the U.S. in chemical development. Of all U.S. patents issued last year in chemical technology, only about half went to U.S. applicants. Japanese applicants garnered 19% of the patents in this area, and West Germans received another 10%. West Germany has claimed about 10% of U.S. chemical patents every year for the past decade. Over the same period, Japan's share of these patents has grown steadily from its 1978 share of 11%. At the same time, U.S. patent holders' share of the total has dropped from 60% to 52%.

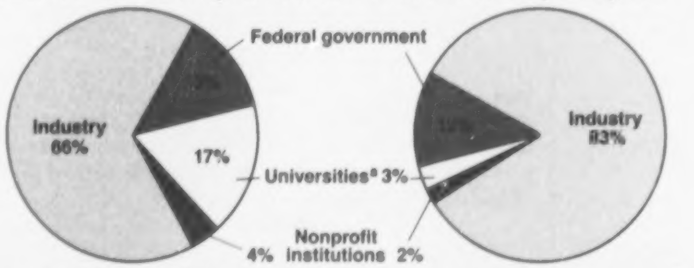
Although industry performs only one fifth of basic research, it does more than 70% of all R&D . . .



Estimated 1988 basic research spending = $15.3 billion

Estimated 1988 total R&D spending = $128 billion

. . . because it does the greater share of both applied research and development, where most money is spent



Estimated 1988 applied research spending = $26.5 billion

Estimated 1988 development spending = $86.4 billion

[a] Includes associated federally funded R&D centers.

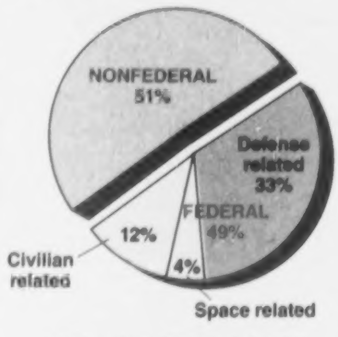
Source: C&EN estimates based on data from the National Science Foundation

Last year, Japan's Fuji Photo ranked fifth among all companies receiving U.S. chemical technology patents. West German-owned Bayer was second, behind Dow Chemical, and two other West German companies—BASF and Hoechst—were also among the top 10. These three West German chemical companies, in fact, received nearly a third of all chemical patents issued during the past decade to the present top 10 recipients of such patents.

Just under half of all financial support for R&D in the U.S. comes from federal sources. Industry supplies almost all of the balance. But unlike many other areas of technology, chemistry and chemical engineering get very little government backing for R&D. Of the roughly $10 billion plowed into such R&D last year, about 90% was money from industrial firms, all but a quarter of it from firms in the overall chemicals and allied products industry, including pharmaceutical producers.

The relatively small amount of federal funds for chemical and chemical engineering R&D, moreover, has been expanding at a rather slow pace recently. This year's total of nearly $900 million will be down 5% from 1987 and is only 7% higher than spending three years ago.

Federal defense spending is a third of all U.S. R&D



Estimated 1988 total R&D spending = $128 billion

Source: National Science Foundation

Clearly, then, the health of chemical R&D is more dependent than that in most other science and engineering disciplines on support from industry—and, more specifically, from the chemical industry. R&D budgets of chemical firms also have been expanding less rapidly during the past few years. Last year, C&EN estimates, R&D outlays by the industry were up 10%, thanks largely to a 15% gain by drug companies; for producers of industrial chemicals, the increase was a more modest 8%. The year before, when the industry was wracked by drastic restructuring and cost-cutting programs, the increase was a mere 4%. During the late 1970s and early 1980s, on the other hand, with pharmaceutical producers again setting the pace, the industry increased its R&D spending at a 16%-a-year clip.

But the slow pace more recently should be viewed in perspective. Inflation in the past five years has been in the moderate 3- to 4%-a-year range, less than half the rate during the previous five years. If inflation is factored out, R&D spending by the chemical industry has been expanding at essentially a steady pace throughout the entire decade. This year, moreover, spending is likely to increase by about the same amount as it did in 1987.

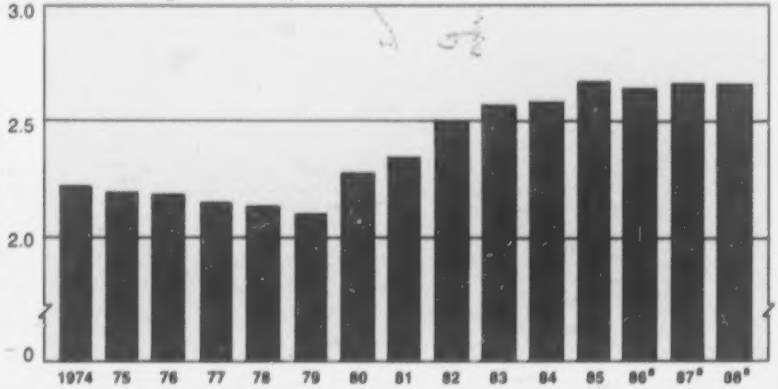
Spending for chemical and chemical engineering research at universities also seems to be slowing. Outlays were up a mere 2% last year, after adjustment for inflation, compared with gains of 9% the two previous years. And because about 70% of university spending in these fields is from federal funds, the decline in government support of chemistry this year may seem disheartening to researchers in academic chemical labs. But the National Science Foundation, the major government source of funding for university R&D in chemistry and chemical engineering, will have 14% more money for all such R&D this year. In fact, more funds from NSF and the National Institutes of Health are boosting total federal funding of university chemical research 9%.

As employment in science and engineering expanded during the 1980s, some significant changes were taking place in the demographic makeup of the science community as well. Both women and minorities are more common in the scientific work force than they were a decade ago, for one thing, though only one minority group—Asians—is represented in anything approaching its proportion in the total population. Women comprised 15% of scientists and engineers in 1986, up from 8.5% in 1976. Nearly 29,000 women work as chemists—16% of the total—and another 11,000 as chemical engineers—8% of that group.

Only 2.5% of the scientific work force was black in 1986, but that's a relatively large gain from the 1.6% representation of this group in 1976. Among chemists and chemical engineers, however, where blacks were 2.0% of the work force in 1976, the proportion has remained unchanged. Asians held 5% of all science and engineering jobs in 1986, as they also did in 1976, and 7% of jobs in chemistry and chemical engineering. □

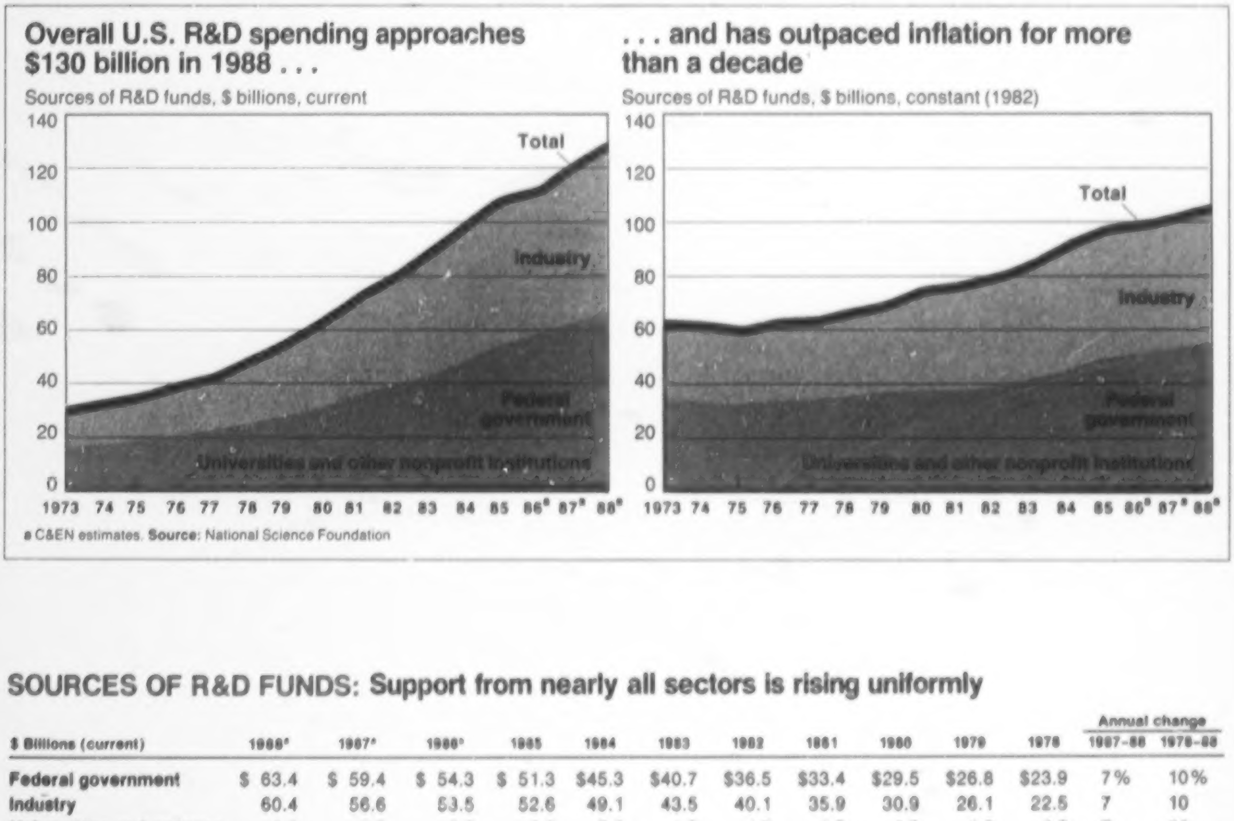
R&D share of U.S. GNP holds at high level

Total R&D as % of gross national product



a C&EN estimates. **Source:** National Science Foundation

Growth in funding slows slightly



Overall U.S. R&D spending approaches $130 billion in 1988 . . .

Sources of R&D funds, $ billions, current

. . . and has outpaced inflation for more than a decade

Sources of R&D funds, $ billions, constant (1982)

a C&EN estimates. **Source:** National Science Foundation

SOURCES OF R&D FUNDS: Support from nearly all sectors is rising uniformly

$ Billions (current)	1988[a]	1987[a]	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Federal government	$ 63.4	$ 59.4	$ 54.3	$ 51.3	$45.3	$40.7	$36.5	$33.4	$29.5	$26.8	$23.9	7%	10%
Industry	60.4	56.6	53.5	52.6	49.1	43.5	40.1	35.9	30.9	26.1	22.5	7	10
Universities and colleges	2.9	2.7	2.5	2.3	2.0	1.9	1.7	1.5	1.3	1.2	1.0	7	11
Other nonprofit institutions	1.5	1.4	1.4	1.3	1.2	1.1	1.0	1.0	0.9	0.8	0.8	5	6
TOTAL	**$128.2**	**$120.1**	**$111.7**	**$107.4**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	**7%**	**10%**
ANNUAL CHANGE	**7%**	**8%**	**4%**	**10%**	**12%**	**10%**	**10%**	**15%**	**14%**	**14%**	**12%**		

$ Billions (1982, constant)	1988[a]	1987[a]	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Federal government	$ 52.2	$ 50.4	$ 47.8	$ 46.2	$42.1	$39.2	$36.5	$35.5	$34.4	$34.1	$33.1	4%	5%
Industry	49.7	48.1	47.0	47.4	45.6	41.9	40.1	38.2	36.1	33.2	31.2	3	5
Universities and colleges	2.4	2.3	2.2	2.1	1.9	1.8	1.7	1.6	1.5	1.5	1.4	4	6
Other nonprofit institutions	1.2	1.2	1.2	1.2	1.1	1.1	1.0	1.1	1.1	1.0	1.1	2	1
TOTAL	**$105.5**	**$102.0**	**$ 98.2**	**$ 96.8**	**$90.6**	**$83.9**	**$79.3**	**$76.4**	**$73.0**	**$69.8**	**$66.8**	**3%**	**5%**
ANNUAL CHANGE	**3%**	**4%**	**1%**	**7%**	**8%**	**6%**	**4%**	**5%**	**5%**	**5%**	**5%**		

Note: Constant-dollar values are calculated by C&EN based on NSF data. a C&EN estimates. **Source:** National Science Foundation

PERFORMERS OF R&D: Industry share, nearly three fourths of total, is fastest growing

$ Billions (current)	1988[a]	1987[a]	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Industry	$ 92.6	$ 86.1	$ 80.6	$ 78.2	$71.5	$63.4	$58.0	$51.8	$44.5	$38.2	$33.3	8%	11%
Federal government	16.4	15.5	13.5	12.9	11.6	10.6	9.1	8.4	7.6	7.4	6.8	6	9
Universities and colleges	11.7	11.2	10.6	9.5	8.5	7.8	7.3	6.8	6.1	5.4	4.6	5	10
University-associated FFRDCs[b]	3.9	3.8	3.6	3.5	3.1	2.7	2.5	2.5	2.2	1.9	1.7	4	9
Other nonprofit institutions	3.6	3.5	3.4	3.3	3.0	2.7	2.4	2.3	2.2	2.0	1.7	4	8
TOTAL	**$128.2**	**$120.1**	**$111.7**	**$107.4**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	7%	10%

$ Billions (1982, constant)	1988[a]	1987[a]	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Industry	$ 76.2	$ 73.2	$ 70.8	$70.5	$66.4	$61.0	$58.0	$55.1	$51.9	$48.6	$46.1	4%	5%
Federal government	13.5	13.2	11.9	11.6	10.8	10.2	9.1	8.9	8.9	9.4	9.4	2	4
Universities and colleges	9.6	9.5	9.3	8.6	7.9	7.5	7.3	7.2	7.1	6.9	6.4	2	4
University-associated FFRDCs[b]	3.2	3.2	3.2	3.2	2.9	2.6	2.5	2.7	2.6	2.4	2.4	1	3
Other nonprofit institutions	3.0	2.9	3.0	3.0	2.8	2.6	2.4	2.4	2.6	2.5	2.4	1	2
TOTAL	**$105.5**	**$102.0**	**$ 98.2**	**$96.9**	**$90.8**	**$83.9**	**$79.3**	**$76.3**	**$73.1**	**$69.8**	**$66.7**	3%	5%

Note: Constant-dollar values are calculated by C&EN based on NSF data. a C&EN estimates. b Federally funded R&D centers. **Source:** National Science Foundation

CHARACTER OF R&D: In real terms, research budgets stall while development funds increase

$ Billions (current)	1988[a]	1987[a]	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Basic research	$ 15.3	$ 14.9	$ 14.1	$ 13.1	$12.0	$11.0	$ 9.9	$ 9.2	$ 8.1	$ 7.3	$ 6.4	3%	9%
Applied research	26.5	25.4	24.1	24.6	22.2	20.4	18.5	16.9	14.1	12.3	10.8	4	9
Development	86.4	79.8	73.5	69.7	63.4	55.8	50.9	45.8	40.5	35.3	30.9	8	11
TOTAL	**$128.2**	**$120.1**	**$111.7**	**$107.4**	**$97.6**	**$87.2**	**$79.3**	**$71.8**	**$62.6**	**$54.9**	**$48.1**	7%	10%

$ Billions (1982, constant)	1988[a]	1987[a]	1986[a]	1985	1984	1983	1982	1981	1980	1979	1978	Annual change 1987–88	Annual change 1978–88
Basic research	$ 12.6	$ 12.7	$ 12.5	$11.8	$11.1	$10.6	$ 9.9	$ 9.8	$ 9.5	$ 9.3	$ 8.9	−1%	4%
Applied research	21.8	21.5	21.2	22.2	20.6	19.6	18.5	18.0	16.5	15.6	15.0	1	4
Development	71.1	67.8	64.5	62.9	58.9	53.7	50.9	48.7	47.3	44.9	42.8	5	5
TOTAL	**$105.5**	**$102.0**	**$98.2**	**$96.8**	**$90.6**	**$83.9**	**$79.3**	**$76.4**	**$73.0**	**$69.8**	**$66.6**	3%	5%

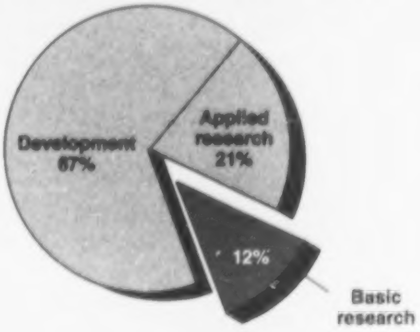
Note: Constant-dollar values are calculated by C&EN based on NSF data. a C&EN estimates. **Source:** National Science Foundation

EMPLOYED SCIENTISTS AND ENGINEERS: Women and minorities increase their participation

Thousands	1986 Total	1986 Women	1986 Blacks	1986 Asians	1986 Hispanic & others	1984 Total	1984 Women	1984 Blacks	1984 Asians	1984 Hispanic & others	1976[a] Total	1976[a] Women	1976[a] Blacks	1976[a] Asians
Scientists	**2186.3**	**599.6**	**73.7**	**94.0**	**56.4**	**1781.4**	**438.1**	**53.4**	**69.1**	**47.4**	**959.5**	**178.2**	**21.4**	**48.5**
Physical	288.4	38.3	6.2	15.4	5.8	254.1	28.3	6.1	12.5	5.4	188.9	16.2	3.2	7.6
Chemists	184.7	28.8	4.8	11.7	3.7	168.6	22.3	5.3	8.5	4.1	132.8	13.7	2.8	6.8
Mathematical and Computer	693.6	196.4	25.7	42.0	14.8	537.2	136.0	16.8	29.3	13.1	167.6	32.1	4.2	5.6
Environmental	111.3	12.9	1.0	2.1	2.2	98.1	10.3	0.6	1.8	2.1	54.8	3.9	2.0	3.2
Life	411.8	102.8	8.8	15.0	12.7	353.3	82.6	6.7	10.4	9.4	213.5	33.9	4.9	5.3
Psychologists and social scientists	681.3	249.2	32.0	19.4	20.9	538.7	180.8	23.2	15.1	17.4	334.8	92.2	7.1	26.8
Engineers	**2440.1**	**99.0**	**41.3**	**132.8**	**60.5**	**2214.1**	**74.5**	**37.1**	**117.5**	**59.5**	**1371.7**	**21.4**	**16.7**	**58.1**
Chemical	149.0	11.2	2.0	10.1	3.6	140.1	8.8	1.5	10.3	3.6	77.5	2.5	1.5	2.4
TOTAL[b]	**4626.5**	**698.6**	**114.9**	**226.8**	**117.0**	**3995.5**	**512.6**	**90.5**	**186.5**	**107.0**	**2331.2**	**199.7**	**38.1**	**106.6**

a Data not collected on Hispanic or other ethnic groups in 1976. b Detail may not add to total due to rounding. **Source:** National Science Foundation

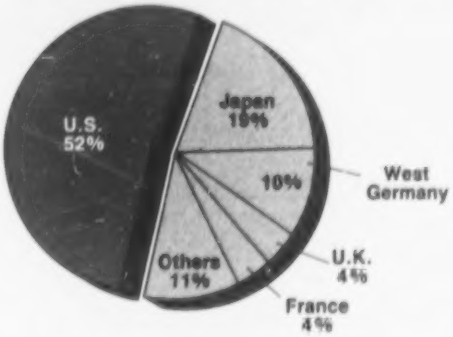
Basic research, the foundation for all R&D, claims only 12% of funds



Estimated total 1988 R&D spending = $128 billion

Source: National Science Foundation

Only about half of U.S. chemical patents go to U.S. firms or individuals



1987 total U.S. chemical patents issued = 21,374

Source: U.S. Patent & Trademark Office

PATENT ACTIVITY OF U.S. COMPANIES: Rebound in 1987 for both chemical and drug firms

Number of patents issued	1987	1986	1985	1984	1983	1982	1981	1980	1979[a]	1978	Total 1978-87
CHEMICAL COMPANIES											
Dow Chemical	469	371	335	328	246	276	260	249	217	334	**3,085**
Du Pont[b]	449	371	395	416	387	331	430	349	287	465	**3,880**
Ciba-Geigy	286	244	305	290	244	281	345	309	248	347	**2,899**
Union Carbide	159	208	242	231	182	202	262	211	197	215	**2,109**
PPG Industries	118	124	128	137	137	177	189	166	118	190	**1,484**
American Cyanamid	107	92	115	111	128	129	188	205	143	225	**1,443**
Stauffer Chemical	94	75	104	95	81	87	94	93	80	132	**935**
Monsanto	91	110	100	138	136	131	211	205	144	264	**1,530**
Celanese	66	66	67	94	57	56	58	56	44	71	**635**
Olin	58	81	117	112	85	80	80	106	82	99	**900**
Dow Corning	58	68	55	52	37	35	50	31	26	49	**461**
Hercules	50	43	41	39	37	30	52	23	24	49	**388**
Ethyl	48	77	105	76	44	31	43	51	25	41	**541**
W. R. Grace	43	42	45	57	52	49	68	72	56	76	**560**
International Flavors & Fragrances	38	76	104	95	87	87	96	76	60	80	**799**
Rohm & Haas	22	33	31	37	55	49	77	74	77	95	**550**
GAF	15	12	23	19	21	32	47	48	54	57	**328**
TOTAL[c]	**2171**	**2093**	**2312**	**2327**	**2016**	**2063**	**2550**	**2324**	**1882**	**2789**	**22,527**
ANNUAL CHANGE	**4%**	**−9%**	**0%**	**15%**	**−2%**	**−19%**	**10%**	**23%**	**−33%**	**6%**	
DRUG COMPANIES											
Merck	123	103	105	135	114	135	160	156	127	150	**1,308**
Warner-Lambert	118	101	73	49	34	25	37	36	36	59	**568**
Hoffmann-LaRoche	86	84	74	78	90	118	124	144	126	186	**1,110**
Eli Lilly	85	82	107	80	74	104	112	85	84	109	**922**
Squibb	75	70	74	53	37	56	62	85	98	136	**746**
Pfizer	67	72	72	89	61	72	92	75	65	89	**754**
SmithKline Beckman	54	27	43	68	59	66	59	82	71	117	**646**
American Home Products	46	38	49	32	24	43	52	52	39	67	**442**
Upjohn	26	66	66	107	73	122	337	170	196	344	**1,507**
TOTAL[c]	**680**	**643**	**663**	**691**	**566**	**741**	**1035**	**885**	**842**	**1257**	**8,003**
ANNUAL CHANGE	**4%**	**−8%**	**−8%**	**21%**	**−26%**	**−28%**	**18%**	**5%**	**−33%**	**15%**	

Note: Includes U.S. chemical and drug companies and U.S. subsidiaries of foreign companies that have received more than 1000 U.S. patents since 1962. a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents. b Includes patents issued to Conoco, acquired in 1981, for all years. c These totals include patents issued to companies in this table only. **Source:** U.S. Patent & Trademark Office

COMPANIES OBTAINING U.S. CHEMICAL PATENTS: Five of top 10 are foreign corporations

Number of patents issued	1987	1986	1985	1984	1983	1982	1981	1980	1979[a]	1978	Total 1978–87
Dow Chemical	415	329	303	299	234	255	230	223	196	288	**2772**
Bayer	354	378	350	351	322	341	484	394	327	408	**3709**
Du Pont	336	268	283	291	273	240	288	241	183	302	**2705**
Ciba-Geigy	277	238	296	285	240	273	337	301	242	338	**2827**
Fuji Photo	252	251	258	180	126	125	181	124	98	125	**1720**
General Electric	248	247	316	277	273	251	304	257	205	287	**2665**
BASF	237	233	246	233	201	217	251	222	154	169	**2163**
Hoechst	217	211	214	202	202	190	236	212	187	272	**2143**
Mobil Oil	191	221	258	269	209	141	174	157	112	186	**1918**
Phillips Petroleum	161	177	225	233	222	174	211	213	176	229	**2021**
Exxon	157	191	243	213	189	167	214	181	190	229	**1974**
Union Carbide	138	169	203	178	151	171	218	177	150	175	**1730**
3M	128	127	126	92	93	105	115	73	61	89	**1009**
Merck	120	100	105	126	112	133	157	149	126	149	**1277**
Eastman Kodak	111	111	127	174	157	166	224	182	160	145	**1557**
Shell Oil	104	125	144	143	131	109	125	126	74	123	**1204**
Texaco	104	102	136	157	122	108	87	62	77	84	**1039**
PPG Industries	102	108	102	113	119	157	155	135	104	147	**1242**
TOTAL	**3652**	**3586**	**3935**	**3816**	**3376**	**3323**	**3991**	**3429**	**2822**	**3745**	**35675**
ANNUAL CHANGE	**2%**	**−9%**	**3%**	**13%**	**2%**	**−17%**	**16%**	**22%**	**−25%**	**−2%**	

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents. **Source:** U.S. Patent & Trademark Office

U.S. CHEMICAL PATENTS: 10% rise last year brings volume back to level of early 1980s

Number of patents issued	1987	1986	1985	1984	1983	1982	1981	1980	1979[a]	1978	Total 1977–86
U.S. origin	**11,208**	**10,408**	**11,430**	**11,377**	**10,470**	**10,557**	**12,619**	**11,157**	**9,234**	**12,887**	**111,347**
to U.S. corporations	9,714	9,117	10,078	10,001	9,067	9,135	10,911	9,605	8,037	11,308	96,973
to U.S. government	322	289	320	377	334	309	364	358	271	397	3,341
to individuals in the U.S.	1,031	910	977	923	974	1,011	1,274	1,116	866	1,099	10,181
to foreign-owned corporations in the U.S.	141	92	55	76	95	102	70	78	60	83	852
Foreign origin	**10,166**	**9,077**	**9,667**	**8,968**	**8,039**	**7,984**	**9,564**	**8,340**	**6,436**	**8,720**	**86,961**
to U.S.-owned corporations abroad	856	758	874	824	700	726	896	814	621	936	8,005
to foreign corporations	8,564	7,643	8,078	7,418	6,688	6,491	7,810	6,751	5,261	7,068	71,772
to foreign governments	197	150	163	167	132	165	100	96	78	85	1,333
to foreign individuals	549	526	552	559	519	602	758	679	476	631	5,851
TOTAL	**21,374**	**19,485**	**21,097**	**20,345**	**18,509**	**18,541**	**22,183**	**19,497**	**15,670**	**21,607**	**198,308**
% Foreign	**47.6%**	**46.6%**	**45.8%**	**44.1%**	**43.4%**	**43.1%**	**43.1%**	**42.8%**	**41.1%**	**40.4%**	**43.9%**

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Patent figures were low in 1979 because the U.S. Patent & Trademark Office was short of funds to print patents. **Source:** U.S. Patent & Trademark Office

HOLDERS OF U.S. CHEMICAL PATENTS: 8% of total shifts from U.S. to Japan since 1978

% of patents	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	Total 1978–87
U.S. origin	**52**	**53**	**54**	**56**	**57**	**57**	**57**	**57**	**59**	**60**	**56**
Foreign origin[a]	**48**	**47**	**46**	**44**	**43**	**43**	**43**	**43**	**41**	**40**	**44**
Japan	19	19	18	16	15	14	13	12	11	11	15
West Germany	10	10	10	10	11	11	11	11	11	10	10
U.K.	4	4	4	4	4	4	4	5	4	5	4
France	4	3	3	3	3	4	4	4	4	4	3
Switzerland	2	2	2	2	2	2	2	3	3	2	2
Canada	1	1	2	1	1	1	1	1	1	2	1
Italy	1	1	1	1	1	1	1	2	1	1	1
Netherlands	1	1	1	1	1	1	1	1	1	1	1
Sweden	1	1	1	1	1	1	1	1	1	1	1
Belgium	1	1	1	1	—	1	1	1	1	1	1
U.S.S.R.	—	—	—	—	—	—	1	1	1	1	—

Note: Includes patents issued in those technology subclasses that the U.S. Patent & Trademark Office classifies as chemical. a Data for individual countries may not equal this number because of rounding. **Source:** U.S. Patent & Trademark Office

ABSTRACTS OF PAPERS IN *CHEMICAL ABSTRACTS:* Two fifths deal with biochemistry

	1987	1986	1985	1984	1983	1982	1977	Change 1977–87
BIOCHEMISTRY	40.5%	40.4%	40.5%	40.5%	38.3%	39.5%	37.9%	2.6%
% of all biochemistry abstracts								
Pharmacology	12.6	12.2	12.3	11.6	11.8	12.0	12.0	0.6
Mammalian hormones[a]	12.2	12.5	12.3	12.4	12.9	12.2	5.5	6.7
Mammalian biochemistry[a]	11.1	10.8	11.1	11.3	11.1	11.6	17.7	−6.6
Toxicology	8.3	7.8	7.9	8.0	8.5	8.1	6.2	2.1
Immunochemistry	5.8	6.1	5.3	4.8	4.2	4.4	3.1	2.7
Biochemical genetics[b]	6.7	6.1	5.2	4.2	3.8	3.3	—	—
Enzymes	5.4	5.6	5.6	5.8	6.1	5.9	6.1	−0.7
Plant biochemistry[a]	5.3	5.2	5.5	6.2	5.9	6.2	5.8	−0.5
Microbial biochemistry[a]	5.1	5.7	5.7	5.2	5.1	5.3	5.3	−0.2
Biochemical methods	4.8	5.0	4.9	4.9	4.9	4.6	5.1	−0.3
General biochemistry	4.6	4.7	4.9	5.3	5.8	6.0	7.0	−2.4
Others	18.1	18.3	19.3	20.3	19.9	20.4	26.2	−8.1
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
PHYSICAL, INORGANIC, AND ANALYTICAL CHEMISTRY	29.0%	29.8%	29.8%	28.8%	29.6%	28.5%	27.9%	1.1%
% of all physical, inorganic, and analytical chemistry abstracts								
Spectra	20.4	20.0	18.4	18.0	17.6	17.2	18.1	2.3
Nuclear chemistry	19.5	19.9	21.8	22.2	22.5	22.6	21.1	−1.6
Electric phenomena	10.9	10.8	10.8	10.8	10.0	10.5	10.5	0.4
General physical chemistry	7.9	7.0	6.9	6.9	7.3	7.3	6.8	1.1
Crystallography and liquid crystals	7.1	7.0	7.5	7.8	8.3	8.7	8.9	−1.8
Analytical chemistry	5.9	6.8	6.1	6.3	6.2	5.4	5.8	0.1
Others	28.3	28.5	28.5	28.0	28.1	28.3	28.4	−0.1
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
APPLIED CHEMISTRY AND CHEMICAL ENGINEERING	18.0%	18.2%	18.4%	17.6%	19.4%	19.5%	19.7%	−1.7%
% of all applied chemistry and chemical engineering abstracts								
Metals and alloys	20.6	20.8	20.0	18.9	19.1	22.2	24.2	−3.6
Water, wastes, and pollution	20.4	21.9	20.2	21.0	19.6	21.7	23.2	−2.8
Mineralogical and geological chemistry	11.2	12.0	12.5	14.6	14.1	13.6	13.4	−2.2
Fossil fuels, derivatives, and related products	9.6	9.0	10.1	10.1	10.3	9.4	9.2	0.4
Unit operations and processes	9.0	7.1	7.5	7.0	7.5	6.9	5.8	3.2
Pharmaceuticals and pharmaceutical analysis	7.8	8.2	8.0	7.0	6.5	6.3	5.6	2.2
Ceramics	6.3	5.8	5.6	5.1	5.4	4.5	4.1	2.2
Others	15.1	15.2	16.1	16.3	17.5	15.4	14.5	0.6
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
ORGANIC CHEMISTRY	6.9%	5.9%	6.4%	7.6%	7.3%	7.2%	8.8%	−1.9%
% of all organic chemistry abstracts								
Physical organic chemistry	23.9	27.3	30.6	32.0	30.5	31.5	41.3	−17.4
Heterocyclic compounds[a]	19.9	15.0	16.1	15.6	16.2	15.6	17.0	2.9
Organometallic and organometalloidal compounds	16.1	18.3	16.2	17.1	16.3	14.8	8.5	7.6
Aromatic compounds[a]	7.7	7.3	6.3	6.3	7.1	7.2	8.5	−0.8
Biomolecules and their synthetic analogs[b]	5.8	5.0	4.9	4.4	4.5	3.7	—	—
Carbohydrates	5.6	7.8	5.7	5.7	5.8	5.8	4.6	1.0
Aliphatic compounds[a]	4.9	4.4	4.2	3.6	4.3	5.2	5.9	−1.0
Amino acids, peptides, and proteins[a]	4.3	3.9	4.6	4.8	4.5	4.4	3.7	0.6
Others	11.8	11.0	11.4	10.5	10.8	11.8	10.5	1.3
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—
MACROMOLECULAR CHEMISTRY	5.6%	5.7%	4.9%	5.5%	5.4%	5.3%	5.7%	−0.1%
% of all macromolecular chemistry abstracts								
Synthetic high polymers	35.2	34.1	34.1	34.0	34.4	34.7	26.5	8.7
Plastics manufacture and uses	23.6	23.8	25.3	24.2	24.4	21.9	27.5	−3.9
Cellulose, lignin, paper, and other wood products	8.8	9.8	9.1	9.6	9.1	9.7	10.0	−1.2
Textiles	8.1	8.8	8.2	7.3	7.9	8.9	11.0	−2.9
Synthetic elastomers and natural rubber	7.2	6.7	6.8	7.3	7.5	7.8	8.5	−1.3
Coatings, inks, and related products	5.8	7.2	7.2	7.8	6.6	7.6	7.5	−1.7
Others	11.3	9.6	9.3	9.8	10.1	9.4	9.0	2.3
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	—

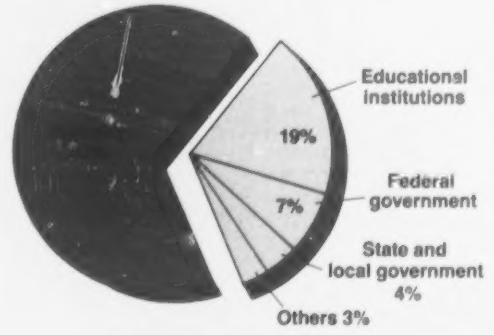
How to read this table: Using biochemistry as an example, 40.5% of all the papers abstracted by Chemical Abstracts Service are in the various subdisciplines of biochemistry; 12.6% of all abstracts in biochemistry, in turn, are in the subdiscipline of pharmacology, and so on. **a** Definition of section changed in 1982. **b** New section in 1982. **Source:** Chemical Abstracts Service

PRIMARY WORK OF SCIENTISTS AND ENGINEERS: 40% of chemists work in R&D

Thousands	Research & development				Management		Teaching	Consulting	Production & inspection	Reporting or computing	Sales	Professional services	Other[a]	TOTAL
	Basic research	Applied research	Development	Total	R&D	Total								
All scientists & engineers	**135.7**	**257.7**	**875.5**	**1268.9**	**398.6**	**1282.2**	**357.8**	**252.1**	**582.6**	**472.8**	**195.4**	**86.0**	**128.8**	**4626.5**
Industry	13.1	117.6	764.8	895.5	294.1	936.4	16.9	226.5	454.9	338.5	184.1	26.0	55.6	**3134.5**
Educational institutions	91.3	62.7	14.9	168.9	19.2	71.5	318.2	4.8	12.6	21.8	2.0	20.9	6.4	**627.0**
Federal government	17.2	44.3	56.7	118.3	51.4	127.5	5.8	7.1	53.8	53.8	2.7	1.9	11.1	**382.0**
State and local government	3.1	13.4	21.3	37.9	13.0	86.0	6.3	6.5	47.6	36.0	3.9	8.0	9.6	**241.7**
Nonprofit organizations	9.4	15.5	12.0	36.9	16.7	50.7	7.3	5.1	8.3	18.2	2.0	28.3	8.5	**165.2**
Other[a]	1.5	4.2	5.6	11.4	4.2	10.1	3.3	2.1	5.4	4.6	0.7	0.7	37.7	**76.1**
Chemists	**11.3**	**26.5**	**35.7**	**73.5**	**24.9**	**46.0**	**25.1**	**2.9**	**28.2**	**3.0**	**3.6**	**0.3**	**2.2**	**184.7**
Industry	2.4	18.9	33.6	54.9	20.4	37.2	0.5	2.9	21.3	1.9	3.5	na	0.8	**122.9**
Educational institutions	6.8	2.2	0.3	9.4	0.7	2.7	23.7	na	0.2	0.1	na	na	na	**36.1**
Federal government	1.6	2.8	1.5	5.9	2.5	3.6	na	na	2.6	0.5	na	0.3	0.1	**13.0**
State and local government	0.2	0.9	na	1.1	0.2	0.8	0.4	na	3.7	0.4	na	na	0.2	**6.6**
Nonprofit organizations	0.2	1.5	0.2	2.0	10.0	1.5	0.4	na	0.2	0.1	na	0.2	0.2	**4.6**
Other[a]	0.1	0.2	na	0.3	na	0.2	na	na	0.2	0.1	na	na	0.7	**1.6**
Chemical engineers	**1.2**	**7.3**	**42.8**	**51.3**	**18.4**	**50.5**	**3.5**	**7.1**	**22.8**	**5.0**	**4.5**	**na**	**4.4**	**149.0**
Industry	0.6	4.4	40.1	45.0	14.4	43.3	0.2	6.7	21.5	4.4	4.3	na	2.8	**128.3**
Educational institutions	0.5	1.8	0.3	2.6	na	1.2	3.3	na	na	na	na	na	0.1	**7.2**
Federal government	na	1.0	1.7	2.8	2.3	3.2	na	na	0.7	0.2	0.1	na	na	**7.1**
State and local government	na	na	0.2	0.2	0.1	1.0	na	na	0.3	0.3	na	na	0.1	**1.9**
Nonprofit organizations	0.1	0.1	0.3	0.4	1.5	1.7	na	0.4	na	na	na	na	0.1	**2.6**
Other[a]	na	0.1	0.2	0.3	na	na	0.1	na	0.2	na	na	na	1.2	**1.9**

Note: Based on 1986 survey. a Includes those not reporting. **Source:** National Science Foundation

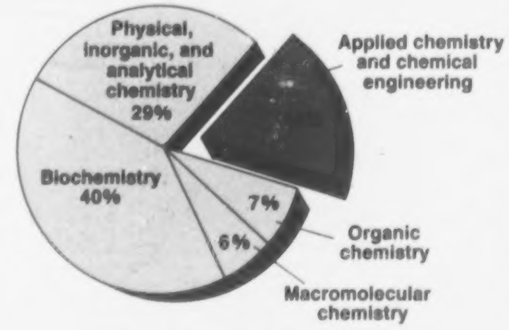
Two out of three chemists are employed by industry



Total chemists employed in 1986 = 184,700

Source: National Science Foundation

Nearly one fifth of chemistry papers are in applied chemistry fields

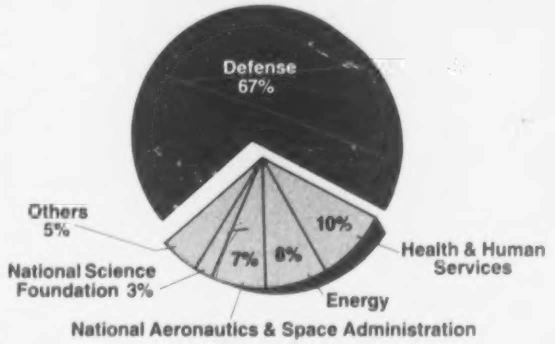


1987 total papers[a] = 476,178

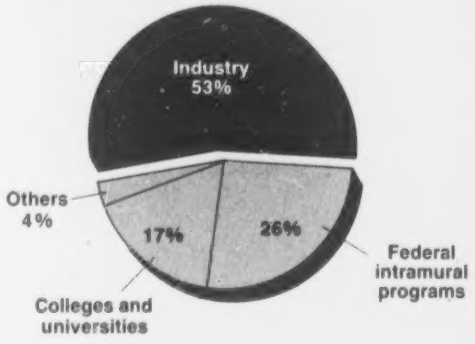
a Number of abstracts of papers published in *Chemical Abstracts*.
Source: Chemical Abstracts Service

Military spending sets the pace

Defense provides two thirds of federal R&D funding, industry gets over half of total



Estimated fiscal 1988 total federal R&D obligations = $63.4 billion



Estimated fiscal 1988 total federal R&D obligations = $63.4 billion

Source: National Science Foundation

FEDERAL OBLIGATIONS FCR R&D: Big gains for Defense and NSF offset declines elsewhere

							Annual change	
$ Millions	1988ª	1987ª	1986	1985	1984	1983	1987–88	1983–88
Defense	$42,662.7	$36,243.9	$32,937.9	$29,791.5	$25,372.9	$22,992.8	18%	13%
Air Force	18,688.0	15,759.7	13,593.8	13,260.9	12,091.6	10,812.6	19	12
Navy	10,562.6	9,503.1	9,650.3	9,127.4	7,605.6	6,068.2	11	12
Army	5,709.0	4,981.9	4,809.4	4,570.8	4,225.5	3,998.1	15	7
Defense agencies	7,416.5	5,833.3	4,767.4	2,781.7	1,391.5	2,052.3	27	29
Health & Human Services	6,282.8	6,342.5	5,657.6	5,451.0	4,830.7	4,352.5	−1	8
National Institutes of Health	5,576.3	5,557.2	5,005.1	4,827.7	4,257.4	3,789.2	0	8
Alcohol, Drug Abuse & Mental Health Administration	479.4	516.3	396.1	377.6	337.2	302.2	−7	10
Energy	4,981.6	4,851.4	4,688.3	4,996.0	4,673.6	4,536.7	3	2
National Aeronautics & Space Administration	4,497.8	4,184.6	3,419.8	3,327.2	2,821.9	2,661.6	7	11
National Science Foundation	1,705.7	1,462.7	1,353.3	1,345.6	1,202.8	1,062.0	17	10
Agriculture	962.5	978.9	928.5	943.0	866.2	847.6	−2	3
Agricultural Research Service	526.5	489.1	463.4	469.7	451.3	443.4	8	3
Cooperative State Research Service	238.3	288.8	269.0	284.3	235.7	232.3	−17	1
Forest Service	122.2	125.8	113.3	113.1	108.4	107.7	−3	3
Interior	371.0	404.6	385.2	391.7	410.9	382.5	−8	−1
Geological Survey^b	217.4	223.1	218.6	214.9	208.9	157.0	−3	7
Environmental Protection Agency	345.7	329.2	317.3	320.4	261.2	240.7	5	8
Commerce	328.1	407.6	399.2	398.8	358.2	335.0	−20	0
National Oceanic & Atmospheric Administration	208.5	288.5	274.7	269.8	244.3	222.0	−28	−1
National Bureau of Standards	106.2	100.2	100.8	100.5	95.5	95.0	6	2
Others	1,258.9	1,286.0	1,325.3	1,367.1	1,426.5	1,300.1	−2	−1
TOTAL	$63,396.8	$56,491.6	$51,412.4	$48,332.3	$42,224.9	$38,711.5	12%	10%
ANNUAL CHANGE	12%	10%	6%	14%	9%	6%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

PERFORMERS OF FEDERALLY FUNDED RESEARCH: Industry's share is growing fastest

Federal obligations, $ millions	1988^a	1987^a	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Industry	$34,006.6	$28,638.6	$26,205.6	$23,759.5	$20,361.5	$18,649.0	19%	13%
FFRDCs^b administered by industry	1,817.2	1,805.3	1,697.0	1,790.8	1,608.4	1,501.2	1	4
Federal intramural programs	16,371.2	15,396.7	13,533.4	12,998.4	11,572.3	10,581.9	6	9
Universities and colleges	10,481.3	9,762.8	9,019.1	8,892.4	7,890.0	7,232.2	7	8
FFRDCs^b administered by universities	2,702.8	2,528.3	2,439.8	2,534.9	2,324.9	2,265.8	7	4
Nonprofit institutions	2,185.1	2,261.0	2,228.1	2,388.4	2,094.4	1,822.9	−3	4
FFRDCs^b administered by nonprofit institutions	702.4	646.2	552.6	689.2	597.1	581.3	9	4
Foreign	241.2	237.6	296.3	244.5	175.8	239.5	2	0
State and local governments	111.5	143.2	128.4	129.4	130.9	186.0	−22	−10
TOTAL	$63,396.8	$56,491.6	$51,412.4	$48,359.6	$42,224.9	$38,711.5	12%	10%

Note: Fiscal years. a Estimated. b Federally funded R&D centers. **Source:** National Science Foundation

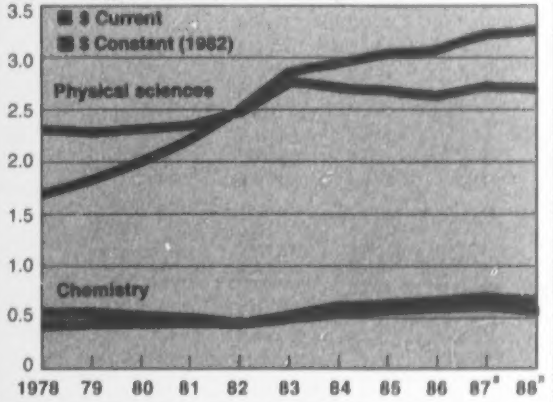
FEDERAL OBLIGATIONS FOR SCIENTIFIC DISCIPLINES: No gain for chemistry

$ Millions for research only	1988^a	1987^a	1986	1985	1984	1983	Annual change 1987–88	Annual change 1983–88
Life sciences	$ 7,092.2	$ 7,078.4	$ 6,464.3	$ 6,366.2	$ 5,635.9	$ 5,177.9	0%	6%
Engineering	3,976.3	3,978.6	3,738.9	3,628.5	3,624.1	3,517.0	0	2
Chemical	201.1	248.8	245.8	254.1	144.5	145.0	−19	7
Metallurgy and materials	459.9	450.1	445.0	439.1	341.1	332.5	2	7
Physical sciences	3,344.0	3,270.0	3,069.1	3,044.0	2,969.0	2,891.4	2	3
Chemistry	692.0	696.0	662.4	644.5	606.4	520.3	−1	6
Physics	1,985.7	1,886.8	1,805.9	1,820.0	1,836.4	1,854.6	5	1
Environmental sciences	1,626.3	1,553.2	1,481.7	1,403.6	1,275.9	1,251.2	5	5
Mathematics and computer sciences	688.1	654.5	615.4	577.5	440.3	419.4	5	10
Other sciences	1,278.4	1,277.4	1,132.8	1,110.3	1,033.6	996.6	0	5
TOTAL	$18,005.3	$17,812.0	$16,502.2	$16,130.1	$14,978.8	$14,253.5	1%	5%
ANNUAL CHANGE	1%	8%	2%	8%	5%	9%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

Federal support for physical sciences and chemistry holding steady in real dollars

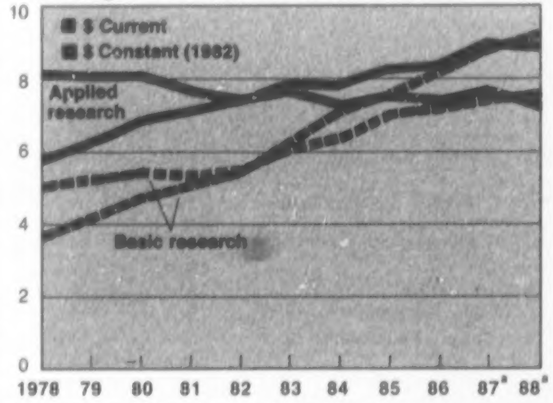
Federal obligations for research, $ billions



Note: Fiscal years. a Estimated. **Source:** National Science Foundation

In real terms, applied research support declines, basic research growth stalls

Federal obligations for research, $ billions



Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR BASIC RESEARCH: NSF posts biggest gain in recent years

							Annual change	
$ Millions	**1988[a]**	**1987[a]**	**1986**	**1985**	**1984**	**1983**	**1987–88**	**1983–88**
Health & Human Services	**$3705.9**	**$3661.0**	**$3338.8**	**$3232.5**	**$2814.5**	**$2475.4**	1%	8%
National Institutes of Health	3446.2	3384.3	3118.6	3018.0	2624.8	2313.0	2	8
Alcohol, Drug Abuse & Mental Health Administration	239.7	256.7	203.4	196.8	170.8	145.0	−7	11
National Science Foundation	**1605.9**	**1378.3**	**1275.2**	**1261.8**	**1132.3**	**999.1**	**17**	**10**
Energy	**1140.0**	**1078.3**	**959.7**	**942.6**	**830.4**	**767.7**	**7**	**8**
National Aeronautics & Space Administration	**1015.5**	**1068.8**	**916.7**	**750.9**	**754.5**	**617.0**	**−5**	**10**
Defense	**910.4**	**861.2**	**923.9**	**861.4**	**847.9**	**785.6**	**6**	**3**
Navy	379.6	342.0	337.3	343.1	315.8	305.4	11	4
Air Force	225.2	205.1	216.5	198.3	192.4	164.2	10	7
Army	202.6	208.0	248.5	240.8	222.1	208.3	−3	−1
Defense agencies	103.0	106.1	121.7	79.2	117.6	107.7	−3	−1
Agriculture	**454.6**	**454.6**	**432.9**	**445.4**	**392.6**	**362.0**	**0**	**5**
Agricultural Research Service	281.6	261.6	247.7	250.2	240.6	215.3	8	6
Cooperative State Research Service	117.8	135.5	131.7	141.5	99.6	98.8	−13	4
Forest Service	46.4	47.7	42.2	44.1	41.2	38.8	−3	4
Interior	**123.0**	**140.9**	**133.0**	**138.3**	**125.9**	**103.0**	**−13**	**4**
Geological Survey[b]	83.1	83.7	83.4	80.5	78.9	64.7	−1	5
Environmental Protection Agency	**38.5**	**38.4**	**38.5**	**38.6**	**29.6**	**22.2**	**0**	**12**
Commerce	**23.9**	**23.8**	**26.5**	**23.2**	**20.6**	**19.2**	**0**	**4**
National Bureau of Standards	23.3	23.3	25.7	22.1	20.2	18.4	0	5
National Oceanic & Atmospheric Administration	0	0	0	0	0	0	—	—
Others	**116.4**	**130.8**	**107.1**	**124.0**	**119.1**	**108.9**	**−11**	**1**
TOTAL	**$9134.1**	**$8821.1**	**$8153.1**	**$7818.7**	**$7067.4**	**$6260.1**	**4%**	**8%**
ANNUAL CHANGE	**4%**	**8%**	**4%**	**11%**	**13%**	**14%**		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR APPLIED RESEARCH: No net gain despite defense increase

							Annual change	
$ Millions	**1988[a]**	**1987[a]**	**1986**	**1985**	**1984**	**1983**	**1987–88**	**1983–88**
Defense	**$2455.9**	**$2333.9**	**$2303.3**	**$2306.9**	**$2200.7**	**$2437.0**	5%	0%
Army	645.2	613.6	578.8	582.6	486.7	485.3	5	6
Air Force	600.0	504.5	542.5	538.4	547.7	524.2	19	3
Navy	458.7	419.6	447.1	448.2	449.6	521.6	9	−3
Defense agencies	752.0	796.1	735.0	737.7	716.6	905.9	−6	−4
Health & Human Services	**2072.0**	**2160.2**	**1850.8**	**1795.8**	**1651.5**	**1545.4**	**−4**	**6**
National Institutes of Health	1628.3	1694.9	1469.0	1410.1	1285.6	1165.2	−4	7
Alcohol, Drug Abuse & Mental Health Administration	238.1	257.4	191.5	179.7	165.2	155.4	−8	9
National Aeronautics & Space Administration	**1494.7**	**1410.6**	**1152.3**	**1032.7**	**954.7**	**927.8**	**6**	**10**
Energy	**920.9**	**1072.4**	**1080.7**	**1198.4**	**1194.5**	**1193.4**	**−14**	**−5**
Agriculture	**472.6**	**490.7**	**463.5**	**465.6**	**442.2**	**455.5**	**−4**	**1**
Agricultural Research Service	214.3	199.1	188.3	191.8	183.7	202.6	8	1
Cooperative State Research Service	120.4	153.3	137.4	142.8	136.2	133.5	−21	−2
Forest Service	72.2	74.3	67.5	65.7	63.9	65.1	−3	2
Commerce	**251.7**	**329.1**	**312.9**	**301.0**	**276.1**	**265.6**	**−24**	**−1**
National Oceanic & Atmospheric Administration	170.2	253.2	237.5	224.4	197.7	188.9	−33	−2
National Bureau of Standards	71.9	66.6	63.5	64.5	63.5	63.1	8	3
Interior	**230.3**	**244.0**	**234.9**	**231.0**	**254.3**	**254.7**	**−6**	**−2**
Geological Survey[b]	124.1	129.2	127.8	130.0	125.1	89.9	−4	7
Environmental Protection Agency	**167.9**	**171.2**	**179.3**	**176.0**	**142.3**	**152.4**	**−2**	**2**
National Science Foundation	**99.8**	**84.4**	**78.1**	**83.8**	**70.5**	**62.9**	**18**	**10**
Others	**705.3**	**694.4**	**693.2**	**720.3**	**724.6**	**698.7**	**2**	**0**
TOTAL	**$8871.2**	**$8990.9**	**$8349.1**	**$8311.5**	**$7911.4**	**$7993.4**	**−1%**	**2%**
ANNUAL CHANGE	**−1%**	**8%**	**0%**	**5%**	**−1%**	**6%**		

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR DEVELOPMENT: Defense, NASA, and EPA all rise substantially

							Annual change	
$ Millions	1988[a]	1987[a]	1986	1985	1984	1983	1987-88	1983-88
Defense	$39,296.5	$33,048.9	$29,710.7	$26,623.2	$22,324.3	$19,770.1	19%	15%
Air Force	17,862.8	15,050.1	12,834.8	12,524.3	11,351.5	10,124.2	19	12
Navy	9,724.2	8,741.5	8,865.9	8,336.1	6,840.2	5,241.2	11	13
Army	4,861.2	4,160.2	3,982.1	3,747.4	3,516.8	3,304.5	17	8
Defense agencies	6,561.6	4,931.1	3,910.7	1,964.8	557.3	1,038.7	33	45
Energy	2,920.7	2,700.6	2,648.0	2,825.0	2,648.7	2,575.6	8	3
National Aeronautics & Space Administration	1,987.6	1,705.2	1,350.8	1,543.6	1,112.7	1,116.8	17	12
Health & Human Services	504.8	521.2	468.0	422.7	364.7	331.7	−3	9
National Institutes of Health	501.9	477.9	417.5	399.6	347.0	311.0	5	10
Alcohol, Drug Abuse & Mental Health Administration	1.6	2.2	1.2	1.1	1.2	1.8	−25	−2
Environmental Protection Agency	139.3	119.5	99.5	105.8	89.2	66.1	17	16
Commerce	52.5	54.7	59.7	74.6	61.5	50.2	−4	1
National Oceanic & Atmospheric Administration	38.3	35.3	37.2	45.4	46.6	33.1	9	3
National Bureau of Standards	11.0	10.3	11.6	14.0	11.8	13.6	6	−4
Agriculture	35.4	33.5	32.1	32.0	31.3	30.0	6	3
Agricultural Research Service	30.6	28.4	27.4	27.7	27.0	25.5	8	4
Forest Service	3.6	3.8	3.6	3.3	3.3	3.8	−3	−1
Interior	17.7	19.9	17.3	22.4	30.7	24.8	−11	−7
Geological Survey[b]	10.2	10.3	7.4	4.4	4.9	2.3	−1	35
National Science Foundation	0	0	0	0	0	0	—	—
Others	437.1	476.1	524.0	552.8	563.0	492.7	−8	−2
TOTAL	$45,391.5	$38,679.6	$34,910.2	$32,202.1	$27,246.1	$24,458.0	17%	13%
ANNUAL CHANGE	17%	11%	8%	18%	11%	4%		

Note: Fiscal years. a Estimated. b Includes Office of Water Research and Technology. **Source:** National Science Foundation

UNIVERSITY RESEARCH: Engineering gets a big boost, chemistry also does well

							Annual change	
Federal obligations, $ millions	1988[a]	1987[a]	1986	1985	1984	1983	1987-88	1983-88
Life sciences	$3814.8	$3575.2	$3251.8	$3192.2	$2800.2	$2460.0	7%	9%
Physical sciences	851.2	786.6	751.9	749.7	697.8	596.5	8	7
Chemistry	308.3	282.9	265.7	266.8	242.3	205.7	9	8
Physics	444.8	413.4	404.7	401.8	375.2	328.8	8	6
Engineering	675.2	590.2	609.0	507.1	474.2	408.7	14	11
Chemical	55.9	52.4	51.1	45.6	51.2	23.6	7	19
Metallurgy and materials	152.4	126.7	133.3	107.2	87.7	86.0	20	12
Environmental sciences	437.9	386.8	365.7	361.1	319.5	316.9	14	7
Mathematics and computer sciences	320.9	292.8	273.9	253.1	181.6	172.4	10	13
Other sciences	427.7	427.0	365.1	347.8	304.1	297.8	−1	8
TOTAL	$6527.7	$6058.6	$5617.4	$5411.0	$4777.4	$4252.3	8%	9%
ANNUAL CHANGE	8%	8%	4%	13%	12%	12%		

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

UNIVERSITY BASIC RESEARCH: Solid funding increases in all major fields

							Annual change	
Federal obligations, $ millions	1988[a]	1987[a]	1986	1985	1984	1983	1987-88	1983-88
Life sciences	$2616.2	$2387.4	$2307.8	$2306.8	$1979.6	$1701.7	10%	9%
Physical sciences	732.9	666.3	636.0	628.8	581.9	502.2	10	8
Chemistry	270.9	244.5	232.5	234.9	212.1	181.9	11	8
Physics	368.0	336.0	325.9	317.0	293.9	264.7	10	7
Engineering	496.6	430.3	429.2	366.6	340.3	295.5	15	11
Chemical	41.0	35.4	33.3	27.6	29.6	18.9	16	17
Metallurgy and materials	134.8	115.0	120.4	95.8	79.9	76.8	17	12
Environmental sciences	405.5	356.4	335.5	330.7	288.9	284.3	14	7
Mathematics and computer sciences	225.7	204.8	188.7	172.1	152.6	146.8	10	9
Other sciences	220.0	213.4	191.0	169.0	147.4	147.2	3	8
TOTAL	$4696.9	$4258.5	$4088.4	$3974.0	$3490.7	$3077.7	10%	9%
ANNUAL CHANGE	10%	4%	3%	14%	13%	14%		

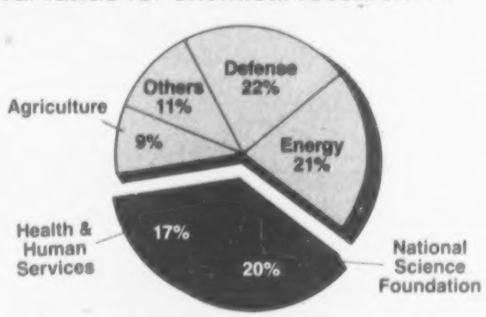
Note: Fiscal years. a Estimated. **Source:** National Science Foundation

FEDERAL OBLIGATIONS FOR CHEMICAL RESEARCH: No net gain despite 11% rise in NSF support

$ Millions	1988[a]	1987[a]	1986	1985	1984	1983	Annual change 1987-88	Annual change 1983-88
Defense	**$151.9**	**$151.7**	**$163.4**	**$156.4**	**$139.8**	**$121.8**	0%	5%
Army	68.6	71.4	81.4	78.2	66.3	59.3	−4	3
Air Force	44.9	39.5	42.0	39.5	36.7	31.2	13	8
Navy	38.4	40.5	39.1	38.3	36.6	31.1	−5	4
Defense agencies	0	0.2	0.9	0.4	0.3	0.3	—	—
Energy	**144.0**	**156.5**	**145.9**	**143.0**	**140.4**	**117.6**	−8	4
National Science Foundation	**137.2**	**124.0**	**112.6**	**115.6**	**109.9**	**92.4**	11	8
Health & Human Services	**116.4**	**117.3**	**104.2**	**99.1**	**86.3**	**74.2**	−1	9
National Institutes of Health	110.0	109.6	99.5	95.1	84.1	72.2	0	9
Alcohol, Drug Abuse & Mental Health	6.4	7.8	4.7	4.0	2.3	2.0	−18	26
Agriculture	**63.6**	**62.8**	**58.6**	**58.0**	**69.0**	**63.8**	1	0
Agricultural Research Service	45.5	42.3	40.0	36.1	51.6	49.5	8	−2
Cooperative State Research Service	11.3	13.6	12.4	16.1	13.5	10.8	−16	1
Forest Service	6.8	7.0	6.2	5.7	3.9	3.6	−3	14
Environmental Protection Agency	**20.1**	**22.9**	**20.1**	**17.5**	**15.9**	**14.8**	−12	6
Interior	**19.9**	**20.7**	**20.3**	**19.4**	**19.2**	**6.2**	−4	26
Geological Survey[b]	19.7	20.5	20.2	19.4	18.4	5.6	−4	29
Commerce	**17.4**	**17.7**	**19.1**	**17.7**	**15.3**	**14.0**	−2	4
National Bureau of Standards	16.1	15.5	16.4	15.4	14.1	12.7	3	5
National Oceanic & Atmospheric Administration	1.3	2.1	2.4	1.4	1.3	1.2	−39	2
National Aeronautics & Space Administration	**14.3**	**14.5**	**11.8**	**16.3**	**7.3**	**9.4**	−1	9
Others	**7.1**	**7.8**	**6.3**	**1.5**	**3.3**	**6.1**	−8	3
TOTAL	**$692.0**	**$696.0**	**$662.4**	**$644.5**	**$606.4**	**$520.3**	−1%	6%
ANNUAL CHANGE	−1%	5%	3%	6%	17%	8%		

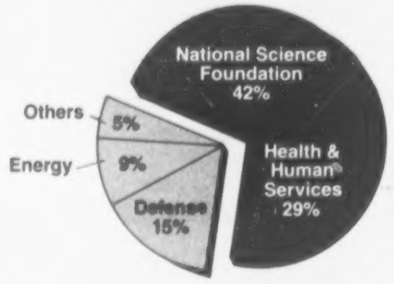
Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

NSF and HHS provide about one third of federal funds for chemical research...



Estimated fiscal 1988 federal chemistry research obligations = $692 million

... but more than two thirds of the funds for chemical research at universities



Estimated fiscal 1988 federal chemistry university research obligation = $308 million

Source: National Science Foundation

UNIVERSITY RESEARCH IN CHEMISTRY: NSF and NIH support 70% of total

Federal obligations, $ millions	1988[a]	1987[a]	1986	1985	1984	1983	Annual change 1987-88	Annual change 1983-88
National Science Foundation	**$127.5**	**$115.3**	**$103.5**	**$108.1**	**$100.7**	**$ 84.7**	11%	9%
Health & Human Services	**88.6**	**81.0**	**75.0**	**75.2**	**63.2**	**51.9**	9	11
National Institutes of Health	87.7	80.0	74.4	74.7	62.8	51.4	10	11
Alcohol, Drug Abuse & Mental Health	0.9	1.1	0.6	0.6	0.4	0.5	−12	15
Defense	**46.5**	**41.9**	**43.2**	**40.4**	**34.7**	**31.4**	11	8
Energy	**29.2**	**26.7**	**27.6**	**26.0**	**26.3**	**18.6**	10	9
Agriculture	**11.2**	**13.3**	**12.2**	**15.5**	**13.5**	**14.5**	−16	−5
National Aeronautics & Space Administration	**5.2**	**4.7**	**4.2**	**4.1**	**4.1**	**4.6**	10	2
TOTAL	**$308.3**	**$282.9**	**$265.7**	**$269.4**	**$242.3**	**$205.7**	9%	8%
ANNUAL CHANGE	9%	6%	−1%	11%	18%	na		

Note: Fiscal years. Data from these six agencies represent approximately 96% of federal obligations for 1988. a Estimated. na = not available. **Source:** National Science Foundation

BAS!C RESEARCH IN PHYSICAL SCIENCES: Boosts by Energy, NSF offset drop by NASA

Federal obligations, $ millions	1988[a] Physical sciences	1988[a] Chemistry	1987[a] Physical sciences	1987[a] Chemistry	1986 Physical sciences	1986 Chemistry	1985 Physical sciences	1985 Chemistry	1984 Physical sciences	1984 Chemistry
Energy	$ 885.5	$119.4	$ 824.2	$121.0	$ 737.1	$110.6	$ 736.1	$102.3	$ 688.4	$108.4
National Aeronautics & Space Administration	538.4	7.1	580.4	8.4	471.9	5.5	377.9	10.2	338.7	5.4
National Science Foundation	402.0	133.2	362.3	120.5	343.7	109.5	347.9	112.7	330.2	106.8
Defense	177.9	70.8	174.0	69.7	192.0	73.3	185.5	70.1	212.2	60.0
Navy	74.7	24.6	74.2	27.4	77.6	26.5	73.9	26.7	100.4	20.7
Air Force	59.9	25.7	54.6	23.5	57.6	24.7	54.1	22.8	48.3	20.3
Army	43.3	20.5	43.4	18.6	50.6	21.2	54.3	20.6	59.8	19.1
Defense agencies	0	0	1.8	0.2	6.2	0.9	3.2	0	3.7	0
Health & Human Services	94.4	87.1	93.8	86.6	85.2	78.7	83.6	75.4	72.0	65.0
National Institutes of Health	91.3	84.2	89.7	82.7	82.7	76.3	81.5	73.3	70.8	63.8
Alcohol, Drug Abuse & Mental Health Administration	3.1	2.9	4.1	3.9	2.5	2.4	2.1	2.1	1.2	1.2
Agriculture	37.1	35.2	35.9	34.1	33.6	31.9	35.6	33.6	45.4	43.5
Agricultural Research Service	28.0	26.9	26.0	25.0	24.7	23.6	25.2	23.9	37.4	36.0
Forest Service	4.6	3.9	4.8	4.0	4.2	3.5	4.0	3.3	2.6	2.1
Cooperative State Research Service	4.4	4.4	5.1	5.1	4.8	4.8	6.4	6.4	5.4	5.4
Commerce	19.4	7.3	19.7	7.7	21.6	8.3	19.7	7.2	16.3	4.8
National Bureau of Standards	19.4	7.3	19.7	7.7	21.3	7.9	18.9	6.4	16.3	4.8
Interior	7.6	6.0	7.7	6.1	7.9	6.3	7.6	6.0	7.1	5.6
Geological Survey[b]	7.6	6.0	7.7	6.1	7.9	6.3	7.6	6.0	7.1	5.6
Environmental Protection Agency	5.9	4.8	6.5	5.2	4.7	4.3	3.5	3.0	3.0	3.0
Others	19.4	4.3	18.3	4.9	16.6	4.9	16.6	0.3	14.7	0.9
TOTAL	$2187.6	$475.4	$2122.8	$464.3	$1914.4	$433.4	$1814.0	$420.8	$1728.0	$403.4
ANNUAL CHANGE	3%	2%	11%	7%	6%	3%	5%	4%	9%	11%

Note: Fiscal years. a Estimated. b Includes Office of Water Research & Technology. **Source:** National Science Foundation

ENGINEERING RESEARCH: Support for all engineering unchanged in 1988 although that for chemical

Federal obligations, $ millions	1988[a] All engineering	1988[a] Chemical engineering	1988[a] Metallurgy & materials	1987[a] All engineering	1987[a] Chemical engineering	1987[a] Metallurgy & materials	1986 All engineering	1986 Chemical engineering
Defense	$1568.0	$ 55.2	$262.5	$1498.8	$ 47.8	$238.6	$1505.6	$ 50.3
Air Force	485.4	7.3	20.4	415.2	2.9	29.0	444.7	1.9
Army	391.8	23.6	25.6	377.6	21.0	24.6	373.6	24.0
Navy	399.6	24.4	114.6	364.5	23.9	105.1	397.8	24.4
Defense agencies	291.1	0	102.0	341.4	0	79.8	289.5	0
National Aeronautics & Space Administration	1343.5	1.2	22.2	1301.8	1.1	22.0	1066.9	1.0
Energy	337.2	59.4	82.6	485.9	127.0	89.8	494.2	121.6
National Science Foundation	276.0	47.3	51.3	224.1	37.7	46.0	199.1	33.4
Interior	77.5	4.6	29.0	101.1	4.8	41.0	93.2	4.7
Transportation	55.0	0.2	0.7	53.9	0.5	1.9	52.8	1.9
Environmental Protection Agency	45.4	23.7	0.5	42.7	20.8	0.5	48.6	23.9
Commerce	45.1	2.8	11.0	44.4	2.6	10.0	41.7	2.6
Agriculture	30.6	6.7	0	34.9	6.5	0	31.1	6.0
Others	198.1	0.1	0.1	191.0	0	0.5	205.9	0.4
TOTAL	$3976.3	$201.1	$459.9	$3978.6	$248.8	$450.1	$3738.9	$245.8
ANNUAL CHANGE	0%	−19%	2%	6%	1%	1%	3%	−3%

Note: Fiscal years. a Estimated. **Source:** National Science Foundation

APPLIED RESEARCH IN PHYSICAL SCIENCES: Energy lowers chemistry funding by 31%

	1988[a]		1987[a]		1986		1985		1984	
Federal obligations, $ millions	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry	Physical sciences	Chemistry
Energy	$ 516.7	$ 24.6	$ 534.1	$ 35.5	$ 529.4	$ 35.3	$ 606.1	$ 40.6	$ 603.5	$ 32.0
Defense	388.4	81.1	376.2	82.0	400.0	90.0	412.0	86.3	477.2	79.8
Army	88.3	48.1	101.8	52.9	109.0	60.1	124.2	57.5	77.4	47.2
Air Force	66.0	19.1	55.5	16.1	59.7	17.3	57.5	16.7	58.6	16.4
Navy	55.3	13.8	52.3	13.1	50.8	12.6	50.7	11.6	69.2	15.9
Defense agencies	178.9	0	166.6	0	180.5	0	179.6	0.4	272.1	0.3
National Aeronautics & Space Administration	96.5	7.2	82.8	6.0	82.7	6.3	76.3	6.1	25.6	1.9
Commerce	35.4	10.0	34.9	10.0	35.1	10.9	35.2	10.5	36.9	10.5
National Bureau of Standards	26.2	8.7	23.9	7.9	24.6	8.5	25.3	9.0	28.1	9.3
National Oceanic & Atmospheric Administration	9.1	1.3	11.1	2.1	10.5	2.4	9.9	1.4	8.9	1.3
Health & Human Services	33.1	29.2	34.7	30.7	29.0	25.6	27.3	23.6	24.7	21.3
National Institutes of Health	29.4	25.8	30.6	26.8	26.5	23.2	25.4	21.8	23.6	20.3
Alcohol, Drug Abuse & Mental Health Administration	3.6	3.4	4.1	3.9	2.5	2.3	1.9	1.9	1.1	1.1
Agriculture	30.5	28.4	30.8	28.7	28.6	26.7	26.4	24.4	27.3	25.5
Agricultural Research Service	19.4	18.6	18.1	17.3	17.1	16.4	13.1	12.2	16.9	15.6
Cooperative State Research Service	6.9	6.9	8.5	8.5	7.6	7.6	9.7	9.7	8.1	8.1
Forest Service	4.1	2.9	4.2	3.0	3.9	2.7	3.5	2.4	2.4	1.8
Environmental Protection Agency	17.3	15.4	18.8	17.7	18.5	15.8	15.7	14.5	13.8	12.9
Interior	16.1	13.9	16.9	14.6	16.2	14.0	15.5	13.3	15.7	13.6
Geological Survey[b]	15.8	13.7	16.7	14.4	16.2	13.9	15.5	13.3	14.9	12.8
National Science Foundation	14.6	4.1	12.9	3.5	12.2	3.1	11.8	2.9	10.9	3.1
Others	8.0	2.8	5.1	2.9	2.9	1.5	3.8	1.4	5.4	2.4
TOTAL	$1156.4	$216.7	$1147.1	$231.8	$1154.6	$229.0	$1230.1	$223.6	$1241.0	$203.0
ANNUAL CHANGE	1%	−7%	−1%	1%	−6%	2%	−1%	10%	−5%	28%

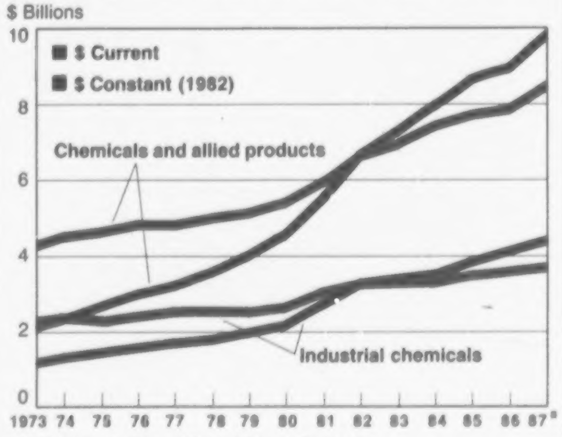
Note: Fiscal years. a Estimated. b Includes the Office of Water Research & Technology. **Source:** National Science Foundation

engineering falls off significantly as a result of drop in Energy funds

1986	1985			1984			1983		
Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials	All engineering	Chemical engineering	Metallurgy & materials
$253.7	$1502.0	$ 53.3	$260.9	$1488.4	$ 38.4	$180.3	$1573.9	$44.9	$179.3
33.4	423.9	1.7	28.6	439.5	3.5	30.3	419.3	3.1	38.2
26.8	344.3	26.7	42.2	324.8	23.5	35.5	318.9	29.3	28.4
117.4	421.2	24.8	121.1	398.4	11.3	53.9	395.5	11.9	50.0
76.2	312.6	0.1	69.0	325.7	0.2	60.6	440.2	0.6	62.8
16.2	931.6	0.6	15.8	967.8	0.3	14.2	799.6	1.0	19.1
82.8	511.3	136.6	66.4	439.0	46.1	68.7	440.2	51.9	62.6
43.5	193.3	32.6	42.7	164.9	27.7	27.3	142.5	21.5	27.3
38.5	100.2	4.8	39.8	111.4	4.5	42.2	91.4	0.4	31.5
1.8	49.4	0.6	1.5	51.1	1.2	1.9	56.1	1.0	1.4
0.5	44.8	18.0	2.6	37.8	17.8	0	47.8	16.7	3.5
7.6	39.8	1.7	6.9	35.3	1.8	6.4	37.4	1.3	7.8
0	28.7	5.6	0	56.7	6.4	0	54.7	6.2	0
0.5	227.4	0.3	0.5	271.7	0.3	0.1	273.4	0.1	0
$445.0	$3628.5	$254.1	$439.1	$3624.1	$144.5	$341.1	$3517.0	$145.0	$332.5
1%	0%	76%	29%	3%	0%	3%	4%	52%	8%

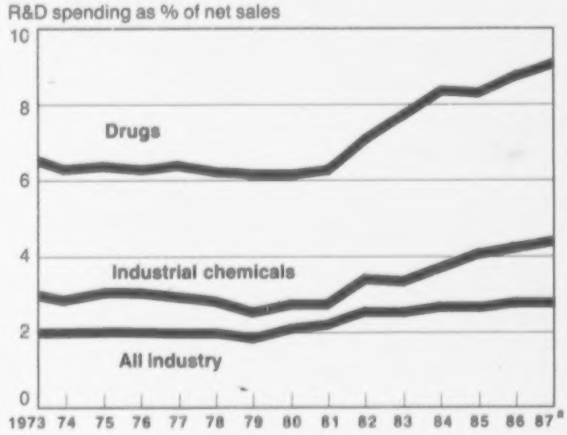
R&D rebounds after slow growth in 1986

Chemical industry R&D outlays keep growing, even after inflation adjustment



a C&EN estimates. **Source:** National Science Foundation

Chemical companies are spending an increasing part of revenues on R&D



a C&EN estimates. **Source:** National Science Foundation

TOTAL FUNDS FOR INDUSTRIAL R&D: Increases run slightly behind 10-year averages

$ Millions	1987a	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	Annual change 1986–87	Annual change 1977–87
Chemicals and allied products	**9,950**	**9,021**	**8,690**	**8,028**	**7,293**	**6,659**	**5,625**	**4,636**	**4,038**	**3,580**	**3,202**	10%	12%
Industrial chemicals	4,400	4,059	3,899	3,512	3,411	3,301	2,802	2,197	1,962	1,798	1,668	8	10
Drugs and other chemicals	5,550	4,962	4,791	4,516	3,882	3,358	2,823	2,439	2,076	1,782	1,534	12	14
Other industries	**76,150**	**71,608**	**70,086**	**63,442**	**56,110**	**51,337**	**46,185**	**39,869**	**34,188**	**29,724**	**26,623**	6	11
TOTAL	**86,100**	**80,629**	**78,776**	**71,470**	**63,403**	**57,996**	**51,810**	**44,505**	**38,226**	**33,304**	**29,825**	7%	11%

a C&EN estimates. **Source:** National Science Foundation

COMPANY FUNDS FOR INDUSTRIAL R&D: A sixth of total spent by chemical industry

$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	**8,773**	**8,391**	**7,797**	**6,845**	**6,226**	**5,205**	**4,264**	**3,692**	**3,250**	**2,907**	**2,751**	5%	12%
Industrial chemicals	3,812	3,618	3,289	2,970	2,879	2,393	1,856	1,617	1,473	1,387	1,275	5	12
Drugs	3,785	3,580	3,381	2,937	2,490	2,064	1,756					6	—
Drugs and Other chemicals (combined)								2,075	1,777	1,520	1,476	—	13
Other chemicals	1,176	1,193	1,126	938	856	747	653					−1	—
Other industries	**44,074**	**43,556**	**40,511**	**36,016**	**33,286**	**30,223**	**26,212**	**22,016**	**18,865**	**16,433**	**14,685**	1	12
TOTAL	**52,847**	**51,947**	**48,308**	**42,861**	**39,512**	**35,428**	**30,476**	**25,708**	**22,115**	**19,340**	**17,436**	2%	12%

Source: National Science Foundation

FEDERAL FUNDS FOR INDUSTRIAL R&D: Only a small share goes to chemical industry

$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	**$ 248**	**$ 299**	**$ 232[a]**	**$ 448**	**$ 434**	**$ 421**	**$ 372**	**$ 346**	**$ 330**	**$ 295**	**$ 266**	−17%	−1%
Industrial chemicals	247	282	223	440	423	409	341	345	325	281	249	−12	0
Drugs and other chemicals	1	17	9	8	11	12	31	1	5	14	17	−94	−25
Other industries	**27,534**	**26,531**	**22,930**	**20,094**	**18,049**	**15,961**	**13,657**	**12,172**	**10,859**	**10,190**	**9295**	**4**	**11**
TOTAL	**$27,782**	**$26,830**	**$23,162**	**$20,542**	**$18,483**	**$16,382**	**$14,029**	**$12,518**	**$11,189**	**$10,485**	**$9561**	**4%**	**11%**

a The decline in 1984 from 1983 results from the administration of federally funded Oak Ridge National Laboratory being changed from a chemical company to a company in the aircraft and missile industry. **Source:** National Science Foundation

R&D BY U.S. COMPANIES ABROAD: Spending was up sharply in 1986

$ Millions	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985–86	Annual change 1976–86
Chemicals and allied products	**$1075**	**$ 847**	**$ 793**	**$ 732**	**$ 684**	**$ 715**	**$ 603**	**$ 500**	**$ 395**	**$ 332**	**$ 312**	**27%**	**13%**
Industrial and other chemicals	523	410	363	354	313	287	245	199	151	133	108	28	17
Drugs	552	437	430	378	371	428	357	301	244	199	204	26	10
Other industries	**3600**	**2818**	**2786**	**2544**	**2413**	**2679**	**2562**	**2254**	**1814**	**1545**	**1347**	**28**	**10**
TOTAL	**$4675**	**$3665**	**$3579**	**$3276**	**$3097**	**$3393**	**$3165**	**$2754**	**$2209**	**$1877**	**$1659**	**28%**	**11%**

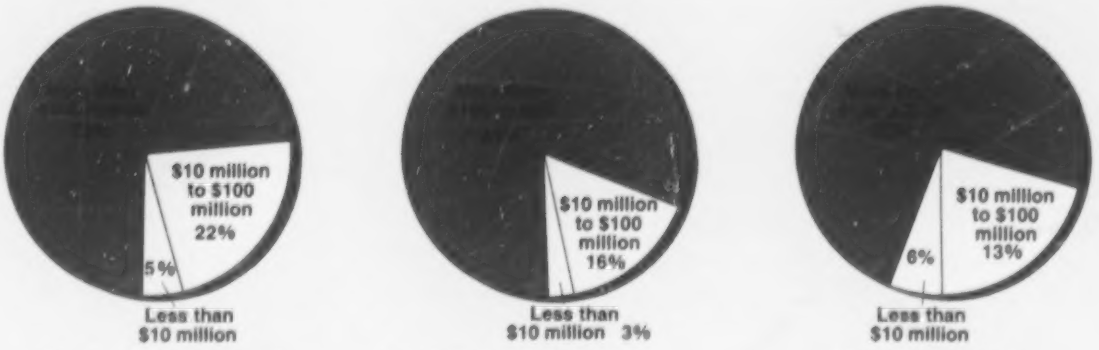
Source: National Science Foundation

CHEMICAL R&D SPENDING: Most chemical producers hiked budgets last year

$ Millions	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1987 R&D spending as % of sales
Du Pont	$1223	$1156	$1144	$1097	$ 966	$ 879	$ 718	$ 591	$ 509	$ 461	$ 367	4.0%
Dow Chemical	670	605	547	507	492	460	404	314	269	232	203	5.0
Monsanto	615	596	470	370	290	264	233	208	161	136	132	8.1
American Cyanamid	314	278	251	232	208	185	166	148	130	108	96	7.5
PPG Industries	227	204	176	150	127	127	119	103	83	70	61	4.4
Union Carbide[a]	159	148	275	265	245	240	207	166	161	156	156	2.3
Rohm & Haas	142	133	124	109	100	92	77	67	54	49	45	6.4
W. R. Grace	107	94	92	81	73	64	57	45	42	37	32	2.4
Hercules	74	71	76	72	74	74	65	57	50	43	40	2.7
Lubrizol	62	51	44	33	37	36	33	28	23	21	19	6.1
Olin	62	56	53	52	49	45	38	31	26	25	25	3.2
Air Products	57	61	51	44	40	37	32	30	24	23	24	2.7
Ethyl	50	47	47	40	39	39	37	34	29	25	28	2.9
International Flavors	45	39	34	32	32	31	30	29	27	24	20	6.0
Pennwalt	45	45	39	36	33	31	27	24	22	23	21	3.9
Nalco Chemical	35	33	32	32	30	33	30	28	21	17	14	4.2
TOTAL	**$3887**	**$3617**	**$3455**	**$3152**	**$2835**	**$2637**	**$2273**	**$1903**	**$1631**	**$1450**	**$1283**	**4.5%**
ANNUAL CHANGE	**7%**	**5%**	**10%**	**11%**	**8%**	**16%**	**19%**	**17%**	**12%**	**13%**	**9%**	

Note: Prior years not restated to reflect company revisions. a Union Carbide divested a substantial part of its business in 1986; on a pro forma basis, R&D spending was $181 million in 1985 and $178 million in 1984. **Source:** Company data

Chemical firms with biggest research budgets do about three fourths of all chemical R&D



1986 chemicals and allied products R&D funds = $9.0 billion

1986 industrial chemicals R&D funds = $4.1 billion

1986 industry R&D funds = $80.6 billion

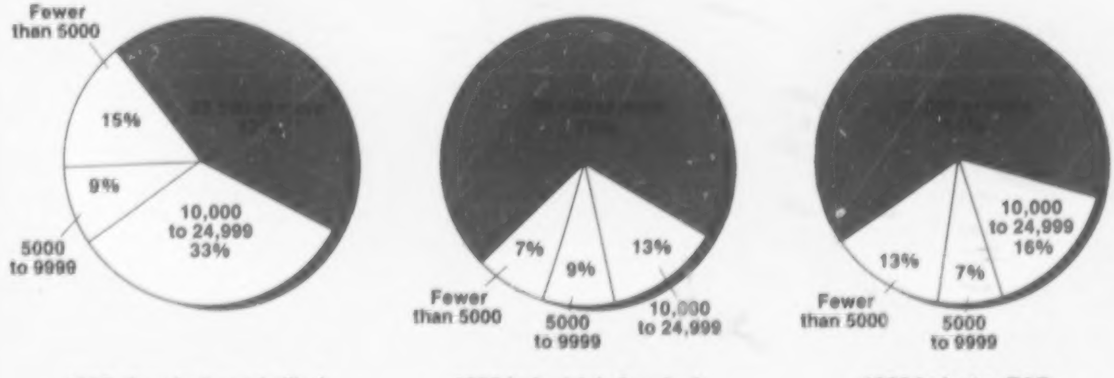
Note: Ranges indicate size of companies' 1986 R&D program. **Source:** National Science Foundation

R&D SCIENTISTS AND ENGINEERS IN INDUSTRY: Not as many are working for chemical firms

Thousands	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1986–87	Annual change 1977–87
Chemicals and allied products	**66.1**	**70.0**	**67.0**	**67.1**	**66.0**	**61.6**	**54.7**	**51.4**	**50.0**	**48.3**	**46.4**	**44.4**	**−6%**	**4%**
Industrial chemicals	27.1	27.1	25.0	26.7	27.2	25.9	21.6	20.9	21.4	21.3	20.6	20.1	0	3
Drugs	29.0	31.6	30.7	30.1	28.2	25.6	23.3	21.6	20.8	19.5	17.8	16.6	−8	5
Other chemicals	10.1	11.3	11.3	10.3	10.6	10.1	9.8	8.9	7.8	7.5	8.0	7.8	−11	2
Other industries	**518.4**	**513.6**	**493.2**	**477.4**	**456.1**	**448.2**	**433.1**	**399.2**	**373.9**	**356.1**	**336.4**	**320.0**	**1**	**4**
TOTAL	**584.5**	**583.6**	**560.2**	**544.5**	**522.1**	**509.8**	**487.8**	**450.6**	**423.9**	**404.4**	**382.8**	**364.4**	**0%**	**4%**

Note: Data as of January of each year for full-time-equivalent personnel. **Source:** National Science Foundation

Companies employing more than 25,000 perform the most R&D



1986 chemicals and allied products R&D funds = $8.8 billion[a]

1986 industrial chemicals R&D funds = $3.8 billion[a]

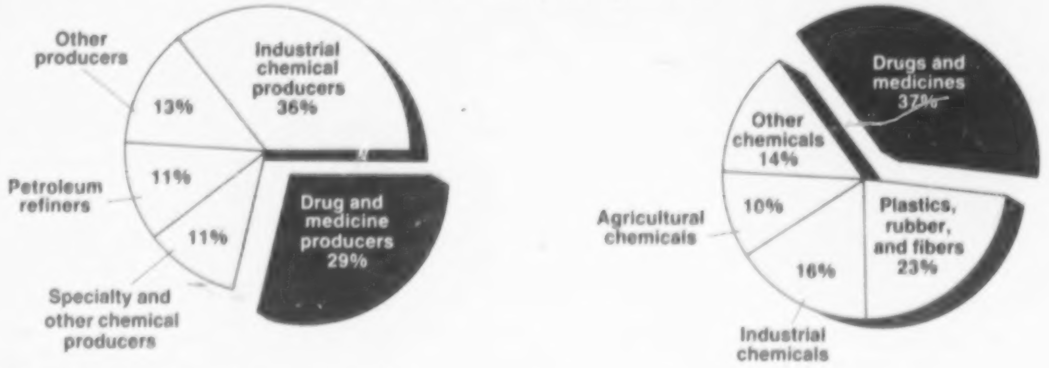
1986 industry R&D funds = $52.8 billion[a]

Note: Ranges indicate companies' number of employees in 1986. a Excludes federal funding. **Source:** National Science Foundation

Drug companies trail industrial chemical producers as performers of chemical R&D . . .

. . . but research on drugs accounts for largest share of R&D funds

1985 chemical R&D spending[a] = $8.0 billion



a Excludes basic research. **Source:** National Science Foundation

BASIC RESEARCH IN INDUSTRY: Chemical companies account for a fourth

$ Millions	1985	1984	1983	1981	1979	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	**$ 708**	**$ 672**	**$ 572**	**$ 539**	**$ 366**	**$337**	**$332**	**$298**	5%	9%
Industrial chemicals	363	338	348	335	190	183	168	155	7	9
Drugs	293	293	195	180	150	130	128	113	0	10
Other chemicals	52	41	29	24	26	25	36	31	27	5
Other industries	**1939**	**1803**	**1580**	**1075**	**792**	**574**	**505**	**432**	8	16
TOTAL	**$2647**	**$2475**	**$2152**	**$1614**	**$1158**	**$911**	**$837**	**$730**	7%	14%

Note: No data for 1978, 1980, and 1982. **Source:** National Science Foundation

APPLIED RESEARCH IN INDUSTRY: Growing more slowly in chemical industry

$ Millions	1985	1984	1983	1981	1979	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	**$ 3,230**	**$ 2,991**	**$ 2,671**	**$ 2,391**	**$1726**	**$1347**	**$1219**	**$1102**	8%	11%
Industrial chemicals		1,525	1,356	1,250	853	695	593	537	—	—
	2,912								8	12
Drugs		1,166	1,043	890	684	479	470	426	—	—
Other chemicals	318	300	272	251	189	173	156	138	6	9
Other industries	**13,804**	**12,037**	**10,834**	**8,308**	**5499**	**4289**	**3964**	**3477**	15	15
TOTAL	**$17,034**	**$15,028**	**$13,505**	**$10,699**	**$7225**	**$5936**	**$5183**	**$4578**	13%	14%

Note: No data for 1978, 1980, and 1982. **Sources:** National Science Foundation, C&EN estimates based on NSF data

DEVELOPMENT IN INDUSTRY: 8% of total outlay is spent by chemical firms

$ Millions	1985	1984	1983	1981	1979	1977	1976	1975	Annual change 1984–85	Annual change 1975–85
Chemicals and allied products	**$ 4,753**	**$ 4,365**	**$ 4,050**	**$ 2,665**	**$ 1,946**	**$ 1,518**	**$ 1,466**	**$ 1,330**	9%	14%
Industrial chemicals			1,707	1,191	920	790	763	700	—	—
	3,916	3,566							10	13
Drugs			1,613	1,000	682	508	493	444	—	—
Other chemicals	837	799	730	475	344	219	209	184	5	16
Other industries	**54,342**	**49,602**	**43,696**	**36,832**	**27,897**	**21,760**	**19,511**	**17,550**	10	12
TOTAL	**$59,095**	**$53,967**	**$47,746**	**$39,497**	**$29,843**	**$23,278**	**$20,977**	**$18,879**	10%	12%

Note: No data for 1978, 1980, and 1982. **Sources:** National Science Foundation, C&EN estimates based on NSF data

R&D SCIENTISTS AND ENGINEERS PER 1000 EMPLOYEES: High among drug companies

	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Chemicals and allied products	**61**	**53**	**54**	**54**	**51**	**44**	**42**	**42**	**43**	**42**	**40**
Industrial chemicals	53	42	44	45	44	37	36	36	38	38	36
Drugs	90	81	88	82	74	66	60	62	65	62	64
Other chemicals	40	39	37	36	36	33	30	27	27	29	28
All industry	**43**	**40**	**38**	**35**	**33**	**29**	**27**	**27**	**27**	**27**	**27**

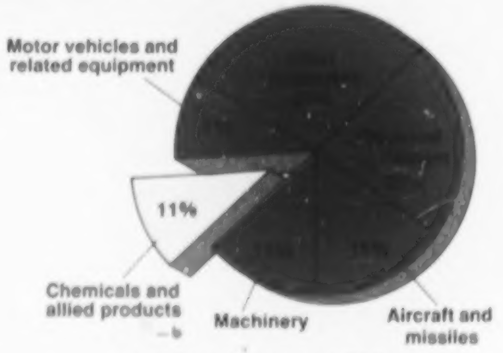
Source: National Science Foundation

COST PER INDUSTRIAL R&D SCIENTIST OR ENGINEER: 4% rise for chemicals in 1986

$ Thousands	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976
Chemicals and allied products	**$132.5**	**$126.9**	**$119.2**	**$109.6**	**$104.4**	**$ 96.6**	**$ 87.4**	**$79.6**	**$72.8**	**$67.6**	**$66.5**
Industrial chemicals	149.6	149.7	a	126.6	124.3	118.0	103.4	92.8	84.2	79.6	74.7
Drugs	125.0	114.9	a	100.7	a	a	79.2	71.4	64.8	59.9	63.4
Other chemicals	110.2	107.1	a	a	a	a	66.5	66.5	61.6	53.8	50.8
All industry	**$138.1**	**$137.8**	**$129.8**	**$118.9**	**$112.4**	**$103.9**	**$ 94.9**	**$87.4**	**$80.4**	**$75.8**	**$72.2**

a Not separately available but included in chemicals and allied products. **Source:** National Science Foundation

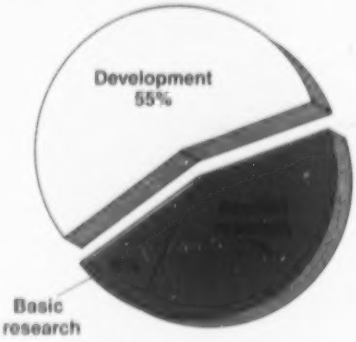
Chemical companies employ 11% of R&D scientists and engineers in industry



1987 total industrial R&D scientists and engineers[a] = 584,500

a Full-time equivalent as of January 1987. **Source:** National Science Foundation

Development claims just over half of chemical industry's R&D spending



1985 total chemical R&D expenditures = $8.69 billion

Source: National Science Foundation

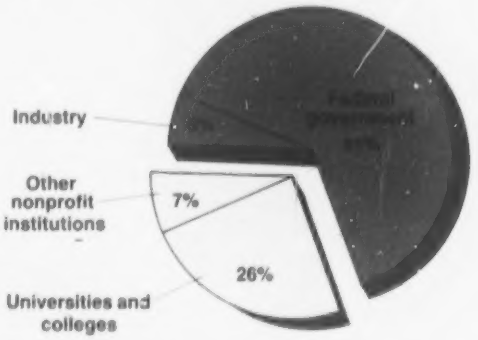
CHEMISTS IN INDUSTRY: Best paid work for chemical producers, drug, and petroleum firms

	% of industrial chemists				Mean salary ($ thousands)[a]		
Industry	All chemists	B.S.	M.S.	Ph.D.	B.S	M.S.	Ph.D.
Pharmaceuticals[b]	16%	15%	19%	16%	$37.9	$44.9	$62.6
Specialty chemicals	15	15	13	15	39.5	45.9	58.8
Basic chemicals	7	4	5	9	43.7	48.9	62.8
Plastics	5	4	6	6	40.7	45.0	62.1
Petroleum and natural gas	4	4	3	4	42.2	50.8	64.5
Coatings	4	6	5	2	38.2	46.0	51.5
Electronics	4	3	3	4	41.0	47.6	62.5
Food	4	4	4	3	40.3	47.4	59.7
Agricultural chemicals	4	3	3	5	39.9	44.1	61.8
Metals and minerals	2	2	2	1	36.0	39.4	53.2
Rubber	2	2	1	1	40.8	40.9	56.6
Soaps and detergents	1	1	1	2	40.3	44.7	61.1
Paper	1	1	2	1	38.0	41.3	56.7
Other manufacturing	18	19	18	18	40.0	49.1	58.9
Nonmanufacturing	12	15	13	9	38.2	46.5	57.1

a As of March 1, 1988; to facilitate comparison, mean salaries are adjusted for differences in average length of experience for each group. b Includes personal care products.
Source: American Chemical Society survey

University R&D growth rate falls to 5%

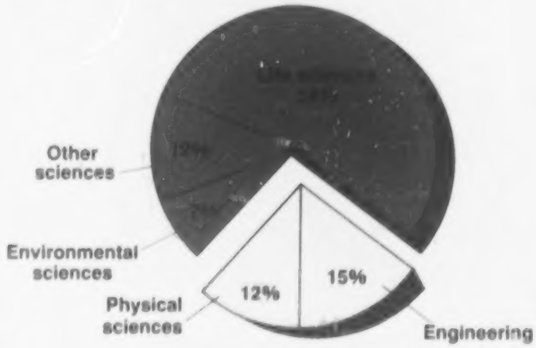
Universities and other nonprofits fund one third of academic R&D



Estimated fiscal 1987 academic R&D expenditures = $11.25 billion

Source: National Science Foundation

More than one fourth of academic R&D is in physical sciences or engineering



Estimated fiscal 1987 academic R&D expenditures = $11.25 billion

Source: National Science Foundation

CHARACTER OF UNIVERSITY R&D SPENDING: Two thirds of total goes to basic research

$ Millions	1987[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978[b]	1977	Annual change 1986–87	Annual change 1977–87
Basic research	$ 7,610	$ 7,244	$6387	$5638	$5265	$4851	$4571	$4027	$3612	$3176	$2800	5%	11%
Applied research	3,020	2,879[a]	2584[a]	2395[a]	2097[a]	2001[a]	1862[a]	1691	1465	1213	1067	5	11
Development	620	596[a]	554[a]	476[a]	436[a]	414[a]	376[a]	343	284	236	200	4	12
TOTAL	**$11,250**	**$10,718**	**$9524**	**$8508**	**$7798**	**$7266**	**$6810**	**$6061**	**$5361**	**$4625**	**$4067**	**5%**	**11%**
ANNUAL CHANGE	**5%**	**13%**	**12%**	**9%**	**7%**	**7%**	**12%**	**13%**	**16%**	**14%**	**9%**		

Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

SOURCE OF UNIVERSITY R&D FUNDS: More than 60% comes from federal government

$ Millions	1987[a]	1986	1985	1984	1983	1982	1981	1980	1979	1978[b]	1977	Annual change 1986–87	Annual change 1977–87
Federal government	$ 6,880	$ 6,633	$5998	$5386	$4953	$4747	$4557	$4097	$3595	$3059	$2726	4%	10%
Universities	2,880	2,677	2286	2033	1880	1687	1517	1318	1198	1037	888	8	12
Industry	720	667	543	461	378	333	291	237	194	170	139	8	18
Other sources	770	740	698	629	587	499	445	408	374	359	314	4	9
TOTAL	**$11,250**	**$10,718**	**$9524**	**$8508**	**$7798**	**$7266**	**$6810**	**$6061**	**$5361**	**$4625**	**$4067**	**5%**	**11%**

Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

FIELDS OF UNIVERSITY R&D SPENDING: **Physical sciences get 12% of total**

$ Millions	1987ᵃ	1986	1985	1984	1983	1982	1981	1980	1979	1978ᵇ	1977	Annual change 1986–87	Annual change 1977–87
All sciences	$ 9,550	$ 9,109	$8138	$7301	$6687	$6241	$5849	$5196	$4593	$4024	$3569	5%	10%
Life	6,020	5,746	5155	4617	4233	3970	3671	3218	2833	2538	2259	5	10
Physical	1,325	1,261	1334	992	897	823	765	677	602	469	424	5	12
Physics	655	622	550	469	414	366	357	322	292	235	202	5	13
Chemistry	485	460	412	368	335	308	284	244	206	183	159	5	12
Environmental	805	774	705	650	619	558	549	509	453	379	319	4	10
Psychology and social	680	640	552	519	493	491	499	453	396	367	353	6	7
Computer	330	315	279	222	175	149	133	114	98	67	56	5	19
Mathematical	160	152	130	124	108	99	89	79	79	59	52	5	12
Others	230	220	182	176	162	152	114	146	134	117	106	5	8
Engineering	1,700	1,609	1387	1207	1111	1026	961	865	768	601	499	6	13
Chemical	130	125	109	96	91	84	83	68	na	na	na	4	—
TOTAL	$11,250	$10,718	$9524	$8506	$7798	$7266	$6810	$6061	$5361	$4625	$4067	5%	11%
ANNUAL CHANGE	5%	13%	12%	9%	7%	7%	12%	13%	16%	14%	9%		

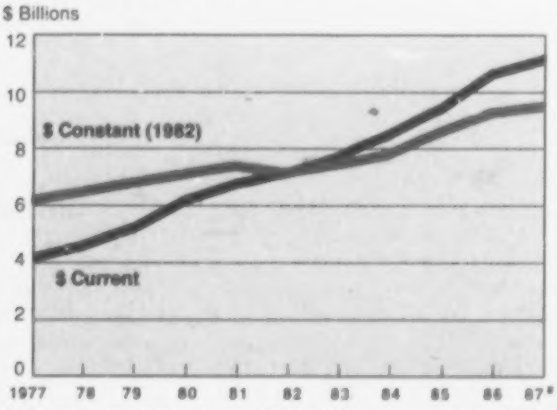
Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. **na** = not available. **Source:** National Science Foundation

FEDERALLY FINANCED R&D SPENDING AT UNIVERSITIES: **Computer field growing strongly**

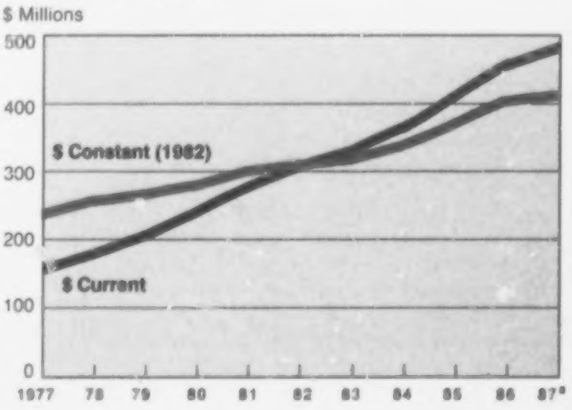
$ Millions	1987ᵃ	1986	1985	1984	1983	1982	1981	1980	1979	1978ᵇ	1977	Annual change 1986–87	Annual change 1977–87
All sciences	$5870	$5665	$5141	$4608	$4216	$4049	$3895	$3502	$3069	$2651	$2389	4%	9%
Life	3550	3440	3141	2796	2563	2493	2363	2095	1819	1626	1474	3	9
Physical	1020	976	883	779	697	649	618	555	491	392	339	5	12
Physics	530	510	455	388	340	306	309	280	253	199	172	4	12
Chemistry	350	338	307	278	248	230	216	189	157	138	122	4	11
Environmental	530	520	478	451	427	391	392	373	329	275	239	2	8
Psychology and social	290	285	262	243	238	251	279	263	227	204	202	2	4
Computer	250	227	193	162	128	107	93	77	69	41	38	10	21
Mathematical	120	112	96	91	76	72	68	61	60	44	41	7	11
Others	110	104	90	86	86	87	82	78	73	68	58	6	7
Engineering	1010	968	856	778	737	698	662	595	526	408	337	4	12
Chemical	70	66	58	54	52	50	55	46	na	na	na	6	—
TOTAL	$6880	$6633	$5998	$5386	$4953	$4747	$4557	$4097	$3595	$3059	$2726	4%	10%
ANNUAL CHANGE	4%	11%	11%	9%	4%	4%	11%	14%	18%	12%	9%		

Note: Data for institutional fiscal years. a C&EN estimates. b NSF estimates, based on data from Ph.D.-granting institutions only. **Source:** National Science Foundation

Growth slows for funding of all academic R&D . . .



. . . and for outlays for academic R&D in chemistry as well



Note: Data for institutional fiscal years. **a** Estimated. **Source:** National Science Foundation

TOP 10 UNIVERSITIES IN R&D SPENDING: Johns Hopkins spends 70% more than any other

$ Millions, fiscal 1986	Physical sciences	Chemistry[a]	Engineering	Environmental sciences	Life sciences	Math & computer sciences	Other sciences	Total
1 Johns Hopkins U	$ 67.7	$ 5.5	$ 138.4	$ 27.8	$ 116.1	$ 76.7	$ 14.1	$ 440.8
2 Massachusetts Inst. of Technology	77.6	13.6	107.9	11.9	34.3	13.2	13.0	257.7
3 U of Wisconsin, Madison	25.9	7.9	25.3	19.3	129.1	7.1	24.4	231.1
4 Cornell U	40.6	7.4	32.6	4.9	124.2	12.0	11.0	225.4
5 Stanford U	40.8	8.3	63.9	3.9	94.0	14.9	5.7	223.2
6 U of Minnesota	12.9	5.1	21.1	4.2	147.3	4.7	11.5	201.7
7 U of Michigan	13.2	2.9	30.5	10.4	88.1	4.5	41.1	187.9
8 U of Washington	11.2	3.0	17.7	19.6	111.2	5.6	21.2	186.6
9 U of California, Los Angeles	17.4	8.0	23.1	10.7	98.4	1.6	17.0	168.2
10 U of California, San Diego	22.9	6.5	2.9	63.5	63.9	4.6	3.2	161.1
TOTAL, FIRST 10 INSTITUTIONS	$ 330.2	$ 68.1	$ 463.4	$176.4	$1006.6	$144.7	$162.3	$ 2,283.6
TOTAL, ALL INSTITUTIONS	$1261.4	$460.1	$1609.1	$774.2	$5746.1	$467.6	$860.1	$10,718.4

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1986 comparisons with data reported in earlier years may be inappropriate in some areas. a Included in physical sciences.
Source: National Science Foundation

GRADUATE SCIENCE STUDENTS: Slight increases for all science and for chemistry

Thousands	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977	1976	Annual change 1985-86	Annual change 1976-86
All sciences	287.2	280.6	274.8	271.7	268.6	265.6	263.5	253.4	245.5	242.2	235.3	2%	2%
Physical sciences	30.6	29.3	28.4	27.7	26.5	25.8	25.4	24.9	24.7	24.8	24.8	4	2
Chemistry	17.6	17.2	16.6	16.5	15.8	15.2	15.1	14.9	14.8	14.6	14.4	3	2
Physics	12.1	11.3	11.0	10.5	10.0	9.9	9.6	9.3	9.2	9.5	9.6	7	2
Life sciences	95.9	93.3	92.4	91.2	90.7	90.9	90.7	87.5	85.9	83.3	77.2	3	2
Biochemistry	4.9	4.7	4.5	4.2	4.1	4.0	4.0	3.9	4.0	3.8	3.7	4	3
Environmental sciences	14.1	14.3	14.3	14.3	13.8	13.1	12.8	12.6	12.2	12.3	11.7	−2	2
Mathematical & computer sciences	41.0	39.1	35.4	33.2	30.3	27.1	25.0	22.7	21.5	21.1	21.7	5	7
Psychology and social sciences	105.6	104.7	104.2	105.4	107.3	108.7	109.7	105.8	101.2	100.6	99.8	1	1
Engineering	97.0	91.4	88.3	86.4	78.2	74.4	70.1	67.2	64.3	64.4	62.9	6	4
Chemical	6.9	7.0	7.2	7.4	6.9	6.3	5.9	5.4	5.2	5.1	5.1	−2	3
Metallurgical & materials	4.0	3.8	3.6	3.3	3.0	3.0	2.8	2.7	2.5	2.5	2.3	6	6
Petroleum	0.7	0.8	0.7	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.4	−9	6
TOTAL	384.2	372.0	363.1	358.1	346.8	340.0	333.7	320.6	309.8	306.6	298.2	3%	3%
ANNUAL CHANGE	3%	2%	1%	3%	2%	2%	4%	3%	1%	3%	1%		

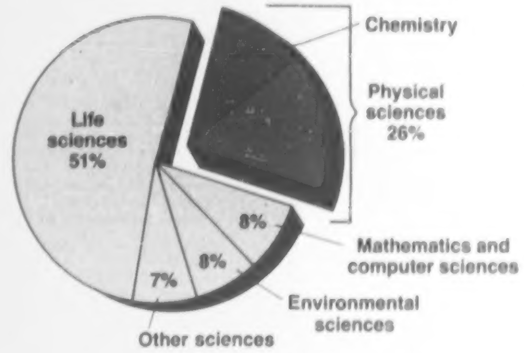
Note: Data for Ph.D.-granting institutions only. **Source:** National Science Foundation

TOP 10 UNIVERSITY R&D CENTERS: Top three get 64% of funds

$ Millions, fiscal 1986	Physical sciences	Engineering	Math & computer sciences	Environmental sciences	Life sciences	Psychology & social sciences	Other sciences	Total
1 Lawrence Livermore Lab	$ 255.1	$ 447.2	$114.3	$ 28.3	$ 23.7	$ 0	$0	$ 868.6
2 Jet Propulsion Lab	96.1	363.8	301.9	80.8	0	0	0	842.6
3 Los Alamos National Lab	378.7	264.4	74.6	17.9	20.2	14.8	7	777.5
4 Lincoln Lab	55.9	207.2[a]	30.9	0	0	0.3[a]	0	294.3
5 Argonne National Lab	83.8	126.7	3.5	31.5	14.0[a]	0	0	259.4
6 Brookhaven National Lab	146.8	32.7	0.8	8.1	20.5	3.0	0.2	212.2
7 Lawrence Berkeley Lab	103.6[a]	16.5[a]	5.5[a]	17.6[a]	30.0[a]	0	1.4[a]	174.6
8 Fermi National Accelerator Lab	148.6	0	0	0	0.5	0	0	149.1
9 Plasma Physics Lab	102.4	0	0	0	0	0	0	102.4
10 Stanford Linear Accelerator Center	80.3	0	0	0	0	0	0	80.3
All others	70.2	3.2	8.2	50.3	5.5	1.6	0	138.9
TOTAL, ALL FEDERALLY FUNDED R&D CENTERS	$1521.4	$1461.6	$539.7	$234.6	$114.4	$19.6	$8.6	$3900.1

Note: Data for university-administered, federally funded R&D centers. a Estimated. **Source:** National Science Foundation

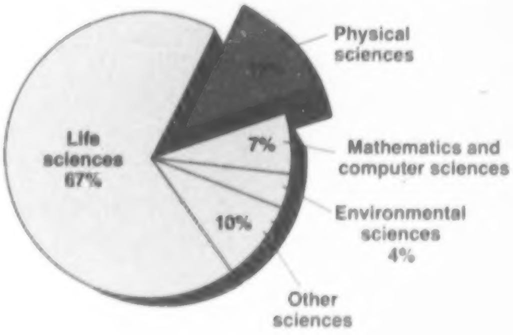
Chemistry departments get a tenth of university scientific equipment funds



1986 university spending for scientific research equipment = $626 million

Source: National Science Foundation

Physical sciences receive 12% of university capital spending on science



1986 university capital spending for all sciences = $1.26 billion

Source: National Science Foundation

UNIVERSITY SPENDING FOR RESEARCH EQUIPMENT: Nearly two thirds is federally funded

	1986		1985		1981		Annual change			
							1985-86		1981-86	
$ Millions	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds	Total	Federal funds
All sciences	$626.0	$415.7	$535.4	$351.2	$345.0	$222.7	17%	18%	13%	13%
Life sciences	318.1	182.7	269.9	151.3	202.2	126.2	18	21	9	8
Physical sciences	164.1	133.4	141.9	113.3	76.1	58.5	16	18	17	18
Physics	88.8	77.1	71.3	60.4	32.5	26.3	25	28	22	24
Chemistry	61.1	45.8	54.0	41.7	35.4	25.9	13	10	12	12
Mathematics & computer sciences	51.5	42.6	44.4	37.4	12.8	6.5	16	14	32	45
Environmental sciences	50.7	35.4	47.0	32.1	31.5	19.2	8	10	10	13
Other sciences	41.6	21.5	32.2	17.0	22.3	12.3	29	26	13	12
Engineering	138.9	81.0	119.2	75.6	69.0	42.4	16	7	15	14
Chemical	13.2	7.7	10.9	6.3	7.0	4.4	22	21	14	12
TOTAL	$764.8	$496.7	$654.7	$426.9	$414.0	$265.0	17%	16%	13%	13%

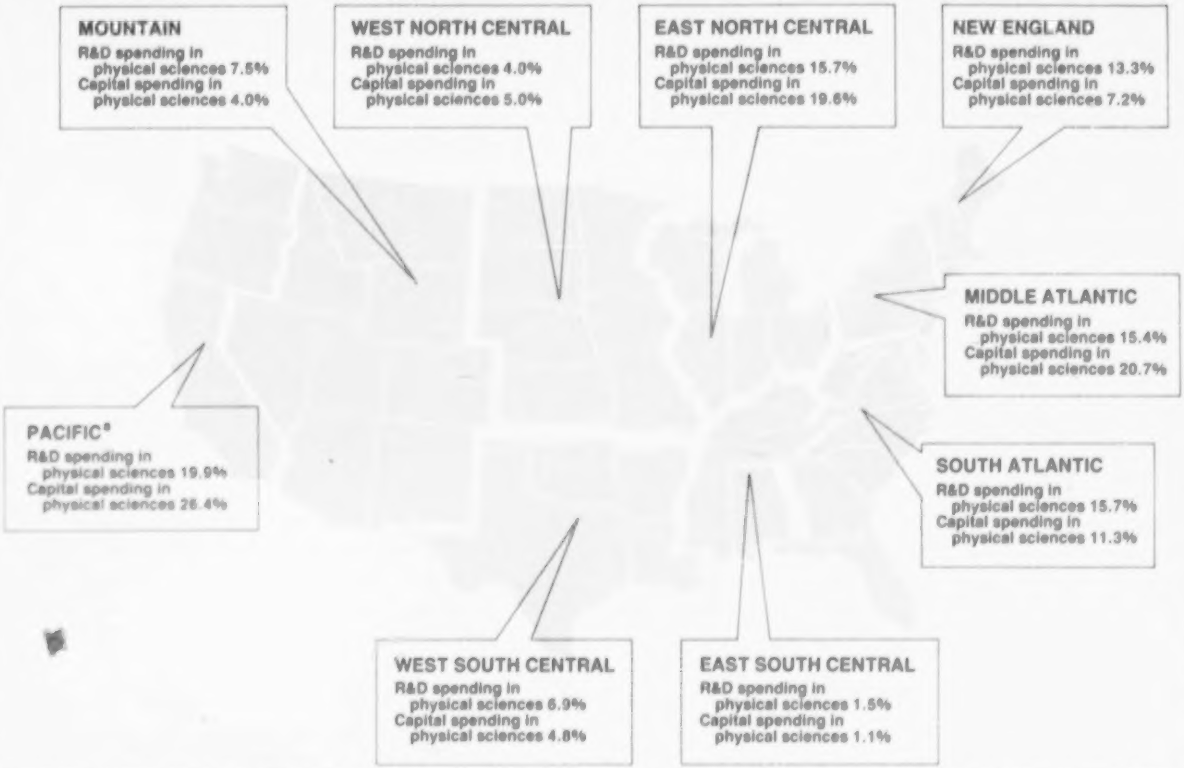
Note: Data for institutional fiscal years. **Source:** National Science Foundation

CAPITAL SPENDING AT UNIVERSITIES: Up strongly, especially for engineering

	1986							Annual change	
$ Millions	Total spending	% federal funds	1985	1984	1983	1982	1981	1985-86	1981-86
All sciences	$1262.4	13%	$1125.3	$1072.4	$ 964.0	$824.7	$849.3	12%	8%
Life sciences	839.9	11	751.6	741.4	678.8	590.4	597.6	12	7
Physical sciences	152.8	23	131.1	116.1	97.5	82.1	87.8	17	12
Mathematical & computer sciences	91.1	15	75.7	50.0	53.1	34.3	30.5	20	24
Psychology & social sciences	76.2	5	82.7	87.1	57.9	43.6	56.1	−8	6
Environmental sciences	47.1	13	54.1	36.8	41.1	42.4	35.0	−13	6
Other sciences	55.3	11	30.1	40.9	35.6	31.9	42.2	84	6
Engineering	316.4	11	187.3	142.9	135.0	144.5	103.3	69	25
TOTAL	$1578.8	12%	$1312.7	$1215.2	$1098.9	$969.1	$952.7	20%	11%
ANNUAL CHANGE	20%	—	8%	11%	13%	2%	20%		

Note: Data for institutional fiscal years. Includes expenditures for facilities and equipment for research, development, and instruction. **Source:** National Science Foundation

Capital spending is concentrated in the Pacific, Middle Atlantic, and East North Central regions, R&D spending on the East and West Coasts

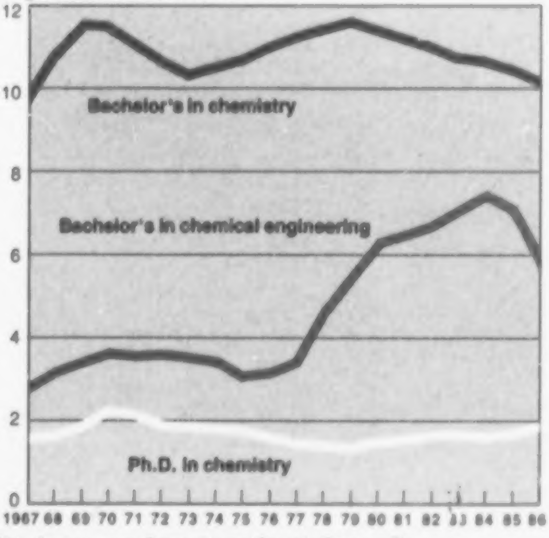

MOUNTAIN
R&D spending in physical sciences 7.5%
Capital spending in physical sciences 4.0%
WEST NORTH CENTRAL
R&D spending in physical sciences 4.0%
Capital spending in physical sciences 5.0%
EAST NORTH CENTRAL
R&D spending in physical sciences 15.7%
Capital spending in physical sciences 19.6%
NEW ENGLAND
R&D spending in physical sciences 13.3%
Capital spending in physical sciences 7.2%
MIDDLE ATLANTIC
R&D spending in physical sciences 15.4%
Capital spending in physical sciences 20.7%
PACIFIC[a]
R&D spending in physical sciences 19.9%
Capital spending in physical sciences 26.4%
SOUTH ATLANTIC
R&D spending in physical sciences 15.7%
Capital spending in physical sciences 11.3%
WEST SOUTH CENTRAL
R&D spending in physical sciences 6.9%
Capital spending in physical sciences 4.8%
EAST SOUTH CENTRAL
R&D spending in physical sciences 1.5%
Capital spending in physical sciences 1.1%

Key to map: Using the Middle Atlantic states as an example, 15.4% of all R&D expenditures in the physical sciences and 20.7% of all capital expenditures in the physical sciences by all Ph.D.-granting universities and colleges are made in this area.

Note: Data based on $10.6 billion of R&D expenditures and $1.56 billion of capital expenditures in the physical sciences at all colleges and universities during the 1986 fiscal year. a Includes Alaska, Hawaii, and outlying areas. **Source**: National Science Foundation

Undergraduate degrees continue to slide

Degrees awarded, thousands



Note: Academic years. **Source**: National Center for Education Statistics

CHEMICAL DEGREES: 18% drop for chemical engineers at bachelor's level

Academic year	Degrees awarded in chemistry			Degrees awarded in chemical engineering		
	Bachelor's	Master's	Ph.D.	Bachelor's	Master's	Ph.D.
1967	9,872	1831	1744	2869	949	305
1968	10,847	2014	1757	3211	1156	367
1969	11,807	2070	1941	3557	1136	409
1970	11,617	2146	2208	3720	1045	438
1971	11,183	2284	2160	3615	1100	406
1972	10,721	2259	1971	3663	1154	394
1973	10,226	2230	1882	3636	1051	397
1974	10,525	2138	1828	3454	1045	400
1975	10,649	2006	1824	3142	990	346
1976	11,107	1796	1623	3203	1031	308
1977	11,322	1775	1571	3581	1086	291
1978	11,474	1892	1525	4615	1237	259
1979	11,643	1765	1518	5655	1149	304
1980	11,446	1733	1551	6383	1271	284
1981	11,347	1654	1622	6527	1267	300
1982	11,062	1751	1722	6740	1285	311
1983	10,746	1604	1746	7145	1304	319
1984	10,704	1667	1744	7475	1514	330
1985	10,482	1719	1789	7146	1544	418
1986	10,116	1754	1908	5877	1361	446

Source: National Center for Education Statistics

SCHOOLS SPENDING MOST ON CHEMICAL R&D: University of Texas makes big jump into top 10

Rank			1986							Annual change	
1986	1985		Total spending ($ thousands)	% federal funds	1985 ($ thousands)	1984 ($ thousands)	1983 ($ thousands)	1982 ($ thousands)	1981 ($ thousands)	1985–86	1981–86
1	1	**Massachusetts Inst. of Technology**	$ 13,593	95%	$ 13,221	$ 11,741	$ 8,914	$ 9,792	$ 8,222	3%	11%
2	6	**California Inst. of Technology**	9,176	83	7,605	6,446	6,994	6,136	6,901	21	6
3	2	**U of California, Berkeley**	9,114	91	10,804	7,850	7,945	6,283	6,553	−16	7
4	10	**U of Illinois, Urbana**	8,604	70	7,079	6,284	5,886	6,422	5,239	22	10
5	27	**U of Texas, Austin**	8,531	58	4,568	6,639	5,938	4,843	4,779	86	12
6	4	**Stanford U**	8,340	90	8,354	6,809	6,375	6,116	5,564	0	8
7	9	**U of California, Los Angeles**	7,954	94	7,243	7,219	5,496	5,187	4,420	10	12
8	8	**U of Maryland, College Park**	7,904	45	7,289	6,324	6,333[a]	4,718[a]	3,109	8	21
9	7	**U of Wisconsin, Madison**	7,892	68	7,350	6,076	5,310	4,567	4,122	7	14
10	5	**Cornell U**	7,376	80	7,962	6,710	5,717[a]	6,239[a]	4,618	−7	10
		Total, first 10 institutions	$ 88,484	79%	$ 81,495	$ 72,098	$ 64,908	$ 60,303	$ 53,527	9%	11%
11	3	**Harvard U**	7,202	94	6,557[a]	6,307[a]	6,898[a]	5,512[a]	6,123[a]	10	3
12	14	**U of Chicago**	7,084	91	6,287	5,735	4,798	4,396	4,139	13	11
13	13	**U of Massachusetts, Amherst**	6,888	63	6,291	6,137	5,162	4,364	3,230	9	16
14	19	**Ohio State U**	6,546	75	5,422	4,104	3,739	2,907	3,227	21	15
15	25	**U of California, San Diego**	6,535	91	4,642	4,355	3,910	3,894	4,430	41	8
16	11	**Pennsylvania State U**	6,438	80	6,509	5,124	4,729	3,564	3,413	−1	14
17	15	**Purdue U**	6,315	90	6,018	5,443	4,542	4,459	4,600	5	7
18	17	**Indiana U**	6,110	78	5,820	5,642	5,551	5,341	3,637	5	11
19	23	**U of Pennsylvania**	6,064	86	5,025	4,375	4,982	3,068	3,386	21	12
20	12	**U of Colorado**	5,830	84	6,360	4,134	3,302	3,492	4,047	−8	8
		Total, first 20 institutions	$153,496	81%	$140,426	$123,454	$112,521	$101,300	$ 93,759	9%	10%
21	16	**Texas A&M U**	5,752	54	5,896	4,610	4,963	4,521	4,069	−2	7
22	32	**Princeton U**	5,702	80	3,963	3,670	3,509	3,062	2,513	44	18
23	20	**Columbia U, main division**	5,555	91	5,188	4,662	4,281	4,700	3,564	7	9
24	29	**Johns Hopkins U**	5,506	89	4,612[a]	4,030	4,592[a]	4,721	4,066	23	6
25	18	**U of Notre Dame**	5,402	93	5,549	4,760	4,022	4,020	3,855	−3	7
26	24	**U of Utah**	5,354	89	4,840	3,830	3,638	3,364	3,076	11	12
27	34	**Georgia Inst. of Technology**	5,260	55	3,684	3,846	3,401	3,327	3,660	43	8
28	21	**Yale U**	5,125	88	5,096	4,134	3,341	2,875	2,781	1	13
29	31	**U of Minnesota**	5,110	79	4,167	4,067	4,047	4,297	4,260	23	4
30	26	**U of Oregon, main campus**	5,087	85	4,640	4,255	3,351	2,971	1,389	10	30
		Total, first 30 institutions	$207,349	81%	$188,061	$165,318	$151,666	$139,158	$126,992	10%	10%
31	30	**U of Florida**	5,050	47	4,380	4,024	2,347	2,248	2,302	15	17
32	28	**U of Pittsburgh**	4,974	81	4,580	3,965	3,267	2,714	2,039	9	20
33	22	**Northwestern U**	4,826	78	5,062	4,557	3,413	3,026	2,995	−5	10
34	33	**U of South Carolina**	4,298	76	3,729	3,423	2,721	2,483	1,087	15	32
35	50	**Syracuse U**	4,240	54	2,900	2,110	2,171	2,868	2,259	46	13
36	36	**Lehigh U**	4,237	41	3,456	3,361	3,664	2,584	1,680	23	20
37	40	**Howard U**	4,155[b]	93	3,269	3,672	2,336	982	1,406	27	24
38	58	**Arizona State U**	4,124	54	2,703	2,875	3,062	2,323	2,153	53	14
39	39	**Florida State U**	4,047	36	3,276	3,137	2,500	2,959	3,012	24	6
40	54	**Colorado State U**	3,867	88	2,775	2,688	2,478	2,479	2,385	39	10
		Total, first 40 institutions	$251,167	76%	$224,191	$199,130	$179,625	$163,824	$148,310	12%	11%
41	38	**Virginia Polytechnic Inst. & State U**	3,786	54	3,417	2,686	2,258	1,740	1,581	13	19
42	47	**Iowa State U**	3,709	36	2,988	2,239	1,903	1,462	1,272	24	24
43	92	**Washington State U**	3,623	67	1,356	692	558	583	na	167	—
44	43	**U of Rochester**	3,584	93	3,196	3,858	3,167	3,123	2,966	12	4
45	61	**Rutgers U**	3,507	61	2,368	2,301	1,830	1,390	1,385	48	20
46	45	**U of California, Santa Barbara**	3,506	88	3,060	2,172	1,902	1,698	1,834	15	14
47	44	**U of California, Irvine**	3,486	97	3,142	2,177	1,777	1,661	1,915	11	13
48	46	**U of Virginia**	3,436	80	3,046	2,516	2,069	1,778	1,781	13	14
49	49	**Wayne State U**	3,405	50	2,903	3,071	2,645	2,656	2,261	63	9
50	42	**U of North Carolina, Chapel Hill**	3,352	87	3,386	2,945	2,397	2,240	2,016	−1	11
		Total, first 50 institutions	$286,561	76%	$253,053	$223,787	$200,131	$182,155	$165,321[c]	14%	12%
		NATIONAL TOTAL	$460,084	73%	$411,615	$367,843	$334,683	$309,371	$285,520	11%	10%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal year 1986 comparisons with data reported in earlier years may be inappropriate in some areas. a Estimated. b Imputed. c. Total does not include spending at Washington State U. **Source:** National Science Foundation

SCHOOLS WITH MOST FEDERAL SUPPORT FOR CHEMICAL R&D: Top 10 get 20% of all support

Rank			1986	1985	1984	1983	1982	1981	Annual change	
1986	1985		($ thousands)						1985–86	1981–86
1	1	**Massachusetts Inst. of Technology**	$ 12,909	$ 12,424	$ 11,055	$ 8,374	$ 9,096	$ 7,572	4%	11%
2	2	**U of California, Berkeley**	8,258	9,892	7,263	7,467	5,691	6,008	−17	7
3	4	**California Inst. of Technology**	7,612	7,001	5,810	6,554	5,809	6,196[a]	9	4
4	3	**Stanford U**	7,524	7,097	6,120	5,968	5,893	5,337	6	7
5	5	**U of California, Los Angeles**	7,516	6,719	6,389	5,047	4,978	4,127	12	13
6	6	**Harvard U**	6,748	6,557	6,307	5,224	4,174	4,637	3	8
7	9	**U of Chicago**	6,472	5,715	5,116	3,998	3,716	3,719	13	12
8	12	**U of Illinois, Urbana**	5,999	5,371	5,005	4,668	4,763	3,847	12	9
9	7	**Cornell U**	5,934	6,293	5,775	4,766	5,437	4,062	−6	8
10	22	**U of California, San Diego**	5,918	4,053	3,780	3,490	3,506	3,933	46	9
		Total, first 10 institutions	$ 69,579	$ 65,450	$ 58,543	$ 52,898	$ 53,063	$ 49,438	6%	7%
11	11	**Purdue U**	5,708	5,418	4,452	3,966	3,946	3,715	5	9
12	13	**U of Wisconsin, Madison**	5,348	5,156	4,391	3,693	3,404	3,134	4	11
13	19	**U of Pennsylvania**	5,232	4,398	3,921	4,037	2,745	3,073	19	11
14	8	**Pennsylvania State U**	5,161	5,860	4,564	4,236	3,222	2,773	−12	13
15	17	**Columbia U, main division**	5,030	4,490	4,639	4,279	4,365	3,471	12	8
16	14	**U of Notre Dame**	4,998	5,097	4,416	3,867	3,866	3,738	−2	6
17	26	**Ohio State U**	4,931	3,846	2,904	2,870	2,355	2,679	28	13
18	42	**U of Texas, Austin**	4,922	2,174	3,873	3,527	2,781	3,017	126	10
19	10	**U of Colorado**	4,911	5,430	3,358	2,695	2,755	3,146	−10	9
20	21	**Johns Hopkins U**	4,903	4,155	3,783	3,604[a]	3,800	3,881	18	5
		Total, first 20 institutions	$123,764	$115,605	$101,423	$ 91,392	$ 86,302	$ 82,065	7%	9%
21	18	**U of Utah**	4,791	4,426	3,380	3,085	2,858	2,720	8	12
22	15	**Indiana U**	4,757	4,885	4,694	4,642	4,237	3,042	−3	9
23	30	**Princeton U**	4,575	3,104	2,892	2,642	2,485	2,142	47	16
24	16	**Yale U**	4,522	4,591	3,528	3,008	2,599	2,609[a]	−2	12
25	23	**U of Massachusetts, Amherst**	4,347	3,993	3,784	3,336	2,773	2,067	9	16
26	25	**U of Oregon, main campus**	4,345	3,959	3,524	2,686	2,530	1,235	10	29
27	27	**U of Pittsburgh**	4,045	3,836	3,343	2,833	2,188	1,581	5	21
28	29	**U of Minnesota**	4,013	3,295	3,346	3,345	3,377	3,494	22	3
29	32	**Howard U**	3,856	2,965	3,300	2,069	867	1,248	30	25
30	24	**Northwestern U**	3,753	3,963	3,471	3,012	2,711	2,813	−5	6
		Total, first 30 institutions	$166,983	$154,968	$135,893	$123,267	$112,927	$105,016	8%	10%
31	28	**U of Maryland, College Park**	3,557	3,323	2,862	2,834	3,068	2,418	7	8
32	37	**Colorado State U**	3,403	2,434	2,426	2,055	2,230	2,079	40	10
33	31	**U of California, Irvine**	3,394	3,035	2,096	1,725	1,593	1,821	12	13
34	34	**U of Rochester**	3,336	2,861	3,490	2,800	2,774	2,553	17	5
35	35	**U of South Carolina**	3,283	2,784	2,533	2,221	1,865	902[b]	18	29
36	20	**Texas A&M U**	3,128	4,195	2,735	3,327	2,823	2,793	−25	2
37	36	**U of California, Santa Barbara**	3,087	2,709	1,881	1,723	1,480	1,628	14	14
38	33	**U of North Carolina, Chapel Hill**	2,929	2,885	2,699	2,381	2,218	1,936	2	9
39	48	**Georgia Inst. of Technology**	2,914	2,051	2,227	2,032	1,800	2,030	42	7
40	44	**U of Southern California**	2,857	2,149	2,495	2,456	1,717	1,639	33	12
		Total, first 40 institutions	$195,359	$179,455	$158,460	$142,345	$134,495	$124,815	9%	9%
41	43	**U of Virginia**	2,748	2,165	2,099	1,663	1,597	1,655	27	11
42	57	**Duke U**	2,482	1,646	1,687	1,372	1,055[b]	924	51	22
43	77	**Washington State U**	2,414	1,211	682	525	na	na	99	—
44	40	**U of Florida**	2,368	2,302	2,042	1,325	1,341	1,156	3	15
45	41	**U of Michigan**	2,367	2,286	2,356	1,853	1,547	1,591	4	8
46	55	**U of Arizona**	2,291	1,738	1,843	1,557	1,228	1,084	32	16
47	66	**Syracuse U**	2,283	1,496	926	826	1,278	551	53	33
48	82	**Georgetown U**	2,252	1,075	822	645	693	774	109	24
49	39	**Arizona State U**	2,218	2,306	2,014	2,124	1,996	1,958	−4	3
50	38	**State U of New York, Stony Brook**	2,210	2,343	2,069	1,809	1,901	2,080	−6	1
		Total, first 50 institutions	$220,491	$201,640	$178,404	$159,034	$147,131[c]	$136,588[c]	9%	10%
		NATIONAL TOTAL	$337,913	$307,214	$277,957	$247,652	$231,108[c]	$216,783[c]	10%	9%

Note: Data for institutional fiscal years. A number of institutions have developed or are in the process of developing new computer systems and methodologies that enable them to report more accurately the total cost of science and engineering research. Fiscal 1986 comparisons with data reported in earlier years may be inappropriate in some areas. a Estimated. b Imputed. c Totals do not include Washington State University, for which data are unavailable. **Source:** National Science Foundation

A1250-1
8/30/88

Carbon clusters:
Research reinforces initial
structural concepts Page 33

AUGUST 29, 1988

CHEMICAL & ENGINEERING NEWS

05111179C098 9 K AR66355SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

POLYETHYLENE

Output limited by tight ethylene supplies
Page 12

Volume 66, Number 35
CENEAR 66 (35) 1–60
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

AUGUST 29, 1988

News of the Week

- **The space shuttle *Discovery* has passed its final two big tests, is set to lift off in about a month.** Page 4
- **Group of scientific societies has written the Presidential candidates with its views on science and technology policy.** Page 5
- **Steps are being taken that could lead to a national system that would provide a computer network to support research.** Page 5
- **Gambling that the University of Houston will be granted patents on high-temperature superconductors, Du Pont has purchased the rights to commercialize them.** Page 6
- **In a move to further bolster its major position in paints and coatings, PPG Industries plans to acquire New York City-based Grow Group.** Page 6

Cover: Union Carbide's Star polyethylene plant at Taft, La.

Letters 2
Editor's Page 3

Concentrates

Business 7
Government 18
Science/Technology 28

The Departments

ACS Focus 40
ACS News 41
People 41
Meetings 43
Newscripts 60

Business

Major changes are taking place in the global pharmaceutical industry, study by British consultant shows. **Page 16**

Government

With work completed on the massive trade bill, Congress is busying itself with a raft of other issues. **Page 22**

Republican platform addresses in detail the party's position on science and technology matters. **Page 24**

EPA rule restricts land disposal of large portion of hazardous wastes, adding considerably to their disposal cost. **Page 26**

Science

Research indicates that 60-carbon buckminsterfullerene species has a spherical structure, is more prevalent than previously thought. **Page 33**

Technology

New strain of bacteria developed at the Institute of Gas Technology selectively removes organic sulfur from coal. **Page 36**

Corrosion problems of construction materials are focus of expert system project at materials institute. **Page 38**

Priestley exhibit of the Beckman Center for the History of Chemistry has been moved to the Joseph Priestley House in Pennsylvania. **Page 38**

A Soviet reconnaissance satellite that is currently losing altitude may hit Earth this fall along with its nuclear-fueled power supply. **Page 39**

Cover Story

Tightening ethylene supplies together with rising demand for polyethylene and other ethylene derivatives have led to higher polyethylene prices and above-optimum plant operating rates. Page 12

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager), Alan Kahan (Art Director), Barbara Fryer (Production/Art Director), Linda Mattingly (Staff Artist), Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83; outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 59)

LETTERS

Membrane technology

SIR: In response to the article by Joseph Haggin, "New Generation of Membranes Developed for Industrial Separations" (C&EN, June 6, page 7), a little fish in the big sea seems to have been overlooked. Please note that A/G Technology Corp. has introduced a series of gas separation membranes for nitrogen enrichment and oxygen enrichment. Some of our industrial customers actually believe A/G Technology is at the cutting edge of hollow-fiber membrane technology. Two recently issued patents suggest we will continue to be a player in this highly competitive field.

Although we are proud of our accomplishments to date and the bright future ahead, we must sadly admit we are not a Fortune 100 company—yet!

Steven J. Polen
A/G Technology Corp.
Needham, Mass.

Abolishing unemployment

SIR: We hear a great deal these days about human rights. We berate our friends and adversaries and at the same time we ignore one of the basic human rights: the right to work.

I heard an interview on one of the networks in which a Vietnam veteran complained that he was unemployed for three years, has a wife and three children, has exhausted all his benefits, and now has only one chance—and that is crime.

Some time ago I saw a letter in C&EN in which a poor Ph.D. chemist complained that he was dismissed after 23 years of service because business was poor. I will never forget his last sentence: "To be unemployed means to die." The medical literature tells us that unemployment will cause not only mental and psychological disturbances but also actual physical illness.

Unemployment creates resentments towards society. The hostility is cumulative and drives people to acts that they would never commit while employed. It is a sad fact that the majority of crimes are committed by the unemployed. The majority of drug addicts are unemployed. It is well known that it costs more to keep a person unemployed than to keep him or her in regular employment. It costs more—much more—to send someone to jail than to Harvard.

Building prisons will not solve the problem. There is so much work to do in our country: eliminate the slums, build adequate and decent housing; beautify the towns and the countryside; repair our dilapidated roads, bridges, and dams; prepare our youth and unemployed for useful occupations, and so on.

We have the materials, the know-how, and the work force. So why don't we abolish unemployment? It will solve many of our most serious problems. And then, only then, could we preach about human rights.

Andrew A. Recsei
Santa Barbara, Calif.

Particle accelerators in space

SIR: We have read with great interest the letter by Robert Pellenbarg on a lunar supercollider (C&EN, May 30, page 3). We have been working for more than a year on the conceptual design of particle accelerators in high Earth orbit (PAHEO). In the phrase "high Earth orbit," we include as a special case, lunar siting. We would like to point out some results of our analysis that are germane to Pellenbarg's letter.

We do concur with the idea that the space environment offers important advantages when designing a PAHEO. Pellenbarg mentions high vacuum, cryogenic temperatures (suitable for high T_c superconductors), promotion of the peaceful use of space, and focusing the space program on a noteworthy goal.

We note that there are several additional advantages; for example, a PAHEO can be enlarged through modular design and can utilize comparatively inexpensive solar power. Fully and aggressively exploiting conditions in space can yield design simplifications with concomitant cost reductions compared with comparable Earth-based facilities for accelerators operating at energies greater than or on the order of 100 TeV.

The time scale that we consider meaningful for implementation of a PAHEO is of the order of 25 years, which places the operation of a PAHEO in the early 21st century. The main consideration is the development of the necessary infrastructure in near-Earth space. This guesstimate coincides with the one obtained from the lunar-Antarctica analogy mentioned by Pellenbarg, since half a century elapsed between the arrival of Amundsen and Scott at the South Pole and the International Geophysical Year

Continued on page 43

Polyethylene, Other Derivatives Feel Worsening Ethylene Crunch

Tight ethylene supply coupled with increasing demand for derivatives of monomer are pushing plant capacity use rates above optimum levels

Bruce F. Greek, C&EN Houston

The supply crunch for ethylene and its derivatives is worsening. Rising demand is pushing capacity use for polyethylene and other ethylene derivatives above optimum levels. However, production of ethylene derivatives this year will depend more on availability of ethylene than on demand or capacity for these derivatives. Polyethylene prices have almost doubled in a year's time, but high prices are doing little yet to dampen vigorous demand growth.

Relief from the current supply and demand crunch for ethylene, polyethylene, and other ethylene derivatives is not expected until the early 1990s. When recently announced large steam crackers go on stream in three years, ethylene consumers will have less difficulty getting ample feedstock.

Because polyethylene capacity use is limited by ethylene supply, this year's polyethylene production will be about 18.6 billion lb, a modest growth of 5 to 6% over 1987 production. Growth of 9.3% last year over 1986 output was the highest growth since 1983, when more than a 10% gain was recorded. The outlook for 1989 is for a smaller gain, because the limits on ethylene supply are expected to continue.

Although monomer supplies are tight, polyethylene capacity continues to grow this year. Several expansions have come on stream or will be coming on stream in 1988. Westlake Polymers plans to restart a 400 million lb-per-year low-density polyethylene unit near Lake Charles, La., that has been shut down since Cities Service exited the business several years ago. Earlier this year, El Paso Products restarted an idled 125 million lb-per-year plant to make LDPE at Bayport, Tex. Capacity of Quantum Chemical's Port Arthur, Tex., plant for LDPE has been increased 300 million lb. In the Baton Rouge, La., area, 95 million lb of high-density polyethylene capacity by Allied-Signal and 70 million lb of LDPE capacity by Exxon Chemical will be added by the end of the year. Phillips 66 will bring on stream an additional 105 million lb of HDPE capacity at Pasadena, Tex., by year's end. Other small debottlenecking activities are likely and will add another 200 million lb-plus to the several types of polyethylene capacity.

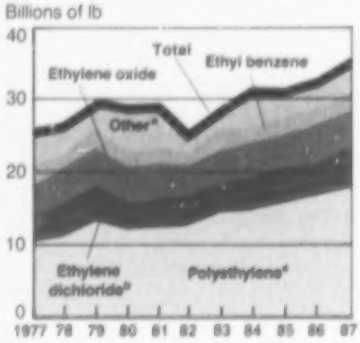
From 1989 to 1991, as much as 5 billion lb of capacity for polyethylene will be added. Current producers all will be represented in those expansions or in expansions occurring in 1988. By the end of 1991, U.S. capacity to make polyethylene will exceed 23.5 billion lb.

Operating rates for polyethylene plants, nevertheless, will remain above 90% of nameplate capacity until at least 1990, says Clark E. Bird, marketing manager for Novacor Chemicals, a major producer of linear low-density polyethylene in Canada. If the announced capacity expansions all are completed on schedule and if sufficient ethylene also somehow becomes available for production levels to meet expected demand, then the average operating rate may decline in 1991 to the mid-80% range. Operating rates likely will again climb later on in the 1990s, Bird says, because demand will grow in both well-established and developing markets.

Global capacity to make polyethylene also is rising. At the end of 1988, world capacity outside the East bloc will be 24.5 billion to 25.0 bil-

Ethylene shortage has delayed HDPE capture of half-gallon milk bottle market

Polyethylene takes growing share of ethylene output



a Includes alpha-olefins, linear alcohols, ethanol, vinyl acetate, ethylene-propylene rubbers, other chemicals, losses, and inventory changes. b About 80% used to make polyvinyl chloride. c Includes copolymers.
Source: C&EN estimates based on data from Society of the Plastics Industry's Committee on Resin Statistics and from U.S. International Trade Commission

lion lb, up from about 22.8 billion lb at the end of 1987, according to John S. Doerr, president of International PC, a consulting firm in Houston. Based on announcements of planned expansions, Doerr forecasts that during the next two years, 6.8 billion lb of capacity will be added outside the East bloc. He says, however, that capacity additions frequently run above initially announced quantities, resulting in revisions to nameplate capacities.

If the large additions to global capacity are completed according to schedule, an overcapacity for making polyethylene could develop. Capacity could rise faster than demand, if demand growth follows historical patterns. Serious overcapacity is unlikely, however, says Earl H. Simpson, manager of chemical analysis at Bonner & Moore Market Consultants in Houston, because demand for polyethylene and other plastics is growing so rapidly in developing countries. As long as polyethylene resins are available, Simpson says, consumption would be more likely limited by the availability of conversion equipment to fabricate products of polyethylene. In China, use of polyethylene is currently at about the per capita level that it was in the U.S. 30 years ago, illustrating the ease with which large capacity expansions under construction in China and large imports of polyethylene will be consumed through demand growth in developing countries.

Large polyethylene capacity expansions outside the U.S. apparently will not dampen U.S. exports, especially of HDPE resins. Imports of LDPE resins in 1987, predominantly from Canada, exceeded exports for the first time in recent history. U.S. exports of LDPE declined in 1987 by more than 150 million lb, to about 700 million lb. Capacity in Canada is now operating fully, so imports from Canada are not expected to rise much during the next two years.

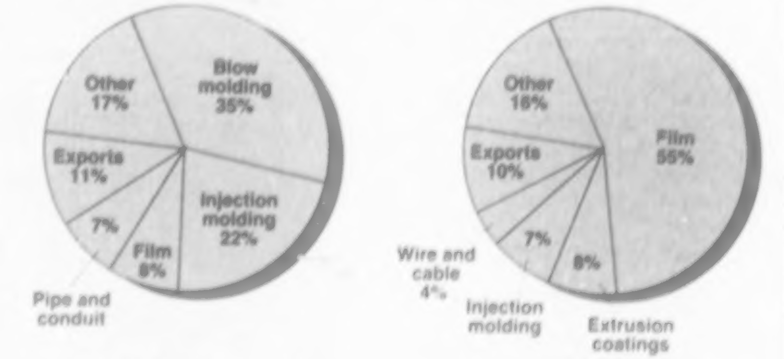
Exports of LDPE, particularly of linear low-density polyethylene, may decline because a large number of LLDPE plants are being built outside the U.S. Another factor affecting exports is that U.S. demand for polyethylene is rising faster than production because of constraints on ethylene availability.

Although prices have climbed from less than 30 cents a lb for grades sold in large volume to more than 50 cents a lb, polyethylene demand in the U.S. and worldwide is still growing strongly. Prices are expected to increase as long as supply remains tight, although producers are attempting to hold down prices lest consumers shift to other materials. Margins for polyethylene producers have risen substantially because price increases have averaged more than 2 cents per lb per month over the past year, even though ethylene prices have more than doubled during this period. Polymer producers may be trying to absorb some of the cost increase in ethylene but are expected to pass on at least part of future increases.

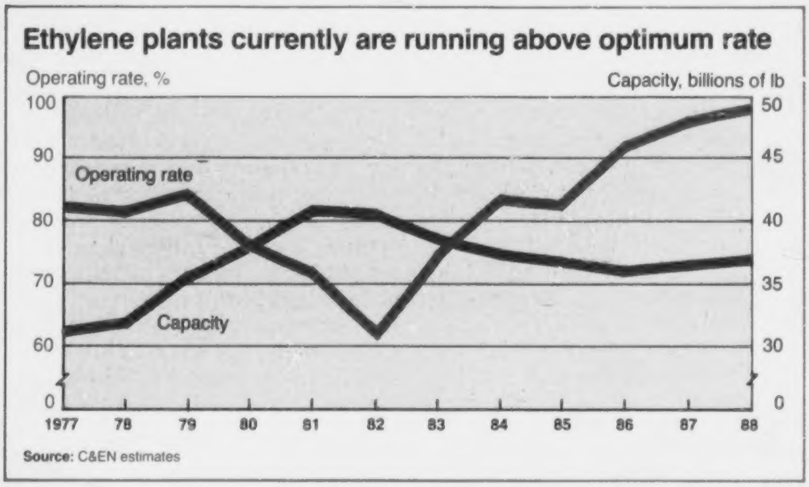
Consumers of polyethylene resins are resisting polymer producers' price increases, according to industry sources. But polymer producers find there is little movement to replace polyethylene in uses that have been captured since these plastics became widely available in the 1950s. The ultimate consumers apparently are willing to accept substantial increases in product costs for the performance of items fabricated from polyethylene. For example, people are not likely to give up HDPE 1-gal milk containers—unless 25 cents or more were added to the total cost. Nor would the many fabricated film uses, such as bread wrappers, be replaced unless substantial amounts were added to the cost of bread.

More likely, capture of new markets will be slower than anticipated, says William C. Kuhlke, a vice president with the Houston-based consulting firm, DeWitt & Co. Kuhlke cites as examples a slower growth in use of HDPE to make storage drums and fuel tanks for trucks and cars, both uses once forecast to grow rapidly because of the potentially lower fabrication costs and corrosion resistance of the polymer. Both long-term supply and anticipated future resin cost weigh heavily in decisions made to change to poly-

Polyethylene use breaks down this way



Source: Committee on Resin Statistics, Society of the Plastics Industry



Ethylene plants currently are running above optimum rate

Source: C&EN estimates

ethylene for uses in which a semipermanent commitment will be required.

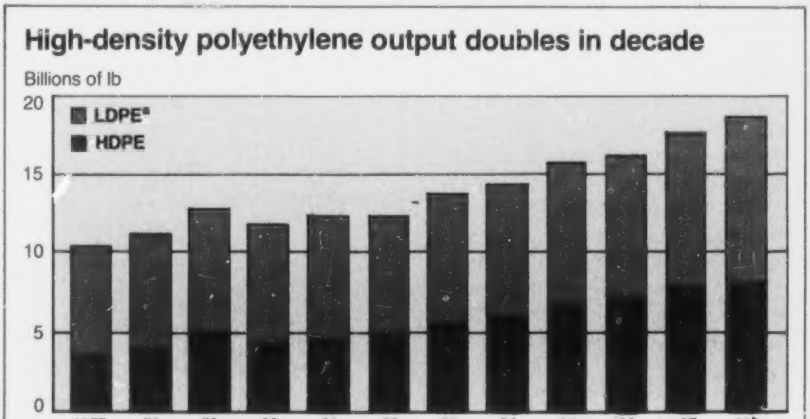
Tightness in polyethylene supply, for at least the next 18 months, will keep present use patterns intact, according to industry sources. The tightness also will limit development of uses within the major market segments. For example, further penetration of HDPE blow-molded milk bottles into the half-gallon size now seems to be in limbo, pending additional supplies of polyethylene suitable for this use. Hence, blow molding uses of HDPE are unlikely to expand their share of consumption. Film uses of both LDPE and LLDPE also are expected to hold their share (about 55%) of total use. Film uses of HDPE, including various kinds of blends with LDPE and LLDPE, have been growing rapidly because of penetration into the grocery and other retail store bag markets. However, supply limits and competition from other uses for HDPE that fetch higher prices could slow growth in film uses. Exports of polyethylene may sag as polymer producers find U.S. consumers more willing to pay higher prices to meet expanding demand for fabricated items.

If growth in polyethylene were not limited by tight ethylene supply, the pattern formed in the early 1980s of HDPE output growing faster than that of LDPE would change. That change would occur because, recently, LDPE growth has improved through the development and rapid acceptance of LLDPE. Both LLDPE capacity and production were forecast to rise at more than 10% annually until the monomer supply crunch hit. Much of the big growth in consumption of LLDPE has been in film, which now accounts for nearly half of the total use. The largest film use is for making trash bags, in which LLDPE provides greater strength than LDPE, thereby permitting thinner films to be used and thus lowering costs. Frequently, blends of LLDPE and LDPE are used in film for cost and performance reasons. The trash bag market has been almost completely captured by LLDPE alone or in blends. However, forecasts of growth in this use of 4 to 6% annually have been revised downward because of the supply and demand crunch.

Most of LLDPE's other film uses, which account for about half, are commercial and industrial packaging, retail store bags, and food packaging. Of these, most are still limited to packaging where very high clarity is not important. Efforts to move LLDPE into markets where clarity is important have lessened, now that meeting total demand takes priority over gaining new markets. LDPE and ethylene-vinyl acetate copolymers blended with LLDPE account for the remainder of the film uses.

Future growth in LDPE use will stem largely from increased demand for LLDPE, which accounts for most of the expansion in capacity. Many of the conventional LDPE plants are old and many have been debottlenecked as much as is economically practical. Thus, capacity growth for these units could amount to less than 1% annually. Some LLDPE capacity can be used to make HDPE, with estimates of this "swing" capacity clustered around 850 million lb of HDPE this year. Much of the new HDPE capacity under construction will be able to make LLDPE, depending on demand for the polymer. Possibly 1 billion lb of capacity additions over the next three years will be used to make HDPE.

The major uses of HDPE remain in blow- and injection-molded items. Bottles for milk, juices, and household products dominate the blow-molded products. A few years ago, HDPE captured most of the 1-gal milk bottle market. A year ago, the resin seemed poised to capture the half-gallon market, but limited res-



High-density polyethylene output doubles in decade

a Includes linear low-density polyethylene. b C&EN estimate.
Source: Committee on Resin Statistics, Society of the Plastics Industry

in supply now has delayed major inroads in this market for two years, according to industry sources.

Shipping pails with separate lids; various kinds of crates, trays, and cases; housewares; and food containers account for most of the HDPE fabricated by injection molding. HDPE encounters competition from polypropylene in several of these applications. Growth in injection-molded HDPE uses will about keep pace with blow-molding uses, except for a temporary dip as tight resin supply likely will allow polypropylene to gain a larger share.

Film uses of HDPE have been growing nearly twice as fast as those for all HDPE uses, but from a smaller base. Bags used in retail stores account for 40 to 50% of this market for HDPE. Most of the film is a blend with other types of polyethylene to capitalize on strength characteristics and thinner film. Until HDPE supply eases, growth rates for film uses are expected to stay below the recent rate of 20% per year.

With output of polyethylene and other ethylene derivatives constrained by ethylene supply, derivative producers, including captive producers, are closely monitoring the outlook for ethylene production. This year, some swings in ethylene output because of plant problems have compounded the supply difficulties. During the second quarter of 1988, Shell Chemical and Texaco Chemical had units with total nameplate capacity of more than 3.4 billion lb go down. Two Shell units at Norco, La., have returned to operation, although they are not yet at full capacity. Texaco also has restarted its Port Arthur, Tex., unit and it has reached capacity. Slightly more than 400 million lb of ethylene apparently were not produced in the second quarter because of these and other interruptions of plant operations, according to data compiled by Ernst & Whinney for the National Petroleum Refiners Association. Inventories of ethylene also were drawn down by about 170 million lb during the second quarter.

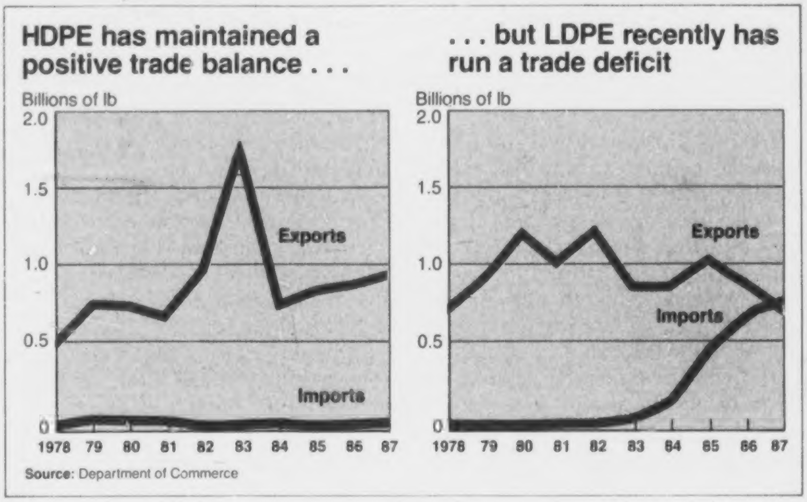
As a result of startup of the Shell and Texaco units and minimal scheduled maintenance shutdowns, third-quarter ethylene production likely will about equal the first quarter's 9.2 billion lb. If no other major plant problems develop for the rest of the year, production of ethylene this year could come close to 36.5 billion lb. To reach that level of production, existing capacity will have to be run at about 98% of the nameplate total for units actually in operation for at least part of the year.

In 1989, Texaco will restart a unit with a capacity of about 350 million lb per year at Port Neches, Tex., and Union Carbide will restart a 450 million lb unit at Taft, La. These units, others that possibly will be restarted, debottlenecking, high use of ethane as one feedstock to steam crackers, and more recovery of ethylene from refinery streams from catalytic cracking could allow an additional output of 1 billion lb of ethylene.

As this additional ethylene becomes available, much of it will be used in derivative units to make ethylene oxide, ethylene dichloride, ethyl benzene, and other chemicals, as well as polyethylene. Earlier this year, production of derivatives other than polyethylene was held down because ethylene was preferentially used in polymers producing higher margins, says Hugh S. Pylant, a senior consultant at Pace Consultants in Houston. However, substantial price increases for other ethylene derivatives, such as 10 cents per lb on July 1 for ethylene oxide to bring its price to 50 cents per lb, have improved margins for those derivatives to about the level of polyethylene, Pylant says.

With margins for ethylene and its derivatives now at levels that permit reinvestment, producers are trying to hold the line on further price increases. Currently the price of ethylene is about 31 cents per lb, the same as in July, and is expected to hold. Until this month, ethylene prices had been rising 1 to 2 cents each month in 1988. Prices for ethylene over the past five years bottomed out about a year ago, at around 13.5 cents per lb.

The rises in ethylene prices designed to bring margins to reinvestment levels have touched off plans for a new round of steam crackers to make ethylene. So far in 1988, decisions to build world-scale units have been made by Dow Chemical, Quantum Chemical, and Phillips Petroleum for a total of 4.5 billion lb. Another 6 billion lb of capacity made up of 0.8 billion lb of restarted old capacity and 5.2 billion lb of other new capacity will be added in the U.S. by 1993, according to William L. Urquhart, manager of chemical planning at Bonner & Moore, who recently has completed a new study on the outlook for ethylene. This 10.5 billion lb of capacity would be a 29% jump over mid-1988 capacity, Urquhart adds, and it suggests a temporary overcapacity. An economic recession, reducing ethylene demand at the same time as new capacity starts up, could send prices down, he says. □


HDPE has maintained a positive trade balance . . .

. . . but LDPE recently has run a trade deficit

Source: Department of Commerce

Global pharmaceutical industry undergoing major shifts

Patricia L. Layman, C&EN London

The world pharmaceutical industry, by some estimates, is worth $100 billion a year. It is increasingly mature, at least in developed countries, and that maturity is affecting many facets of the industry in ways ranging from research and development to relationships with governments where companies are located. And the balance of power in the industry is slowly but surely shifting from the established power bases to new ones, in the face of massively increasing amounts needed to stay in the business.

Those are some of the conclusions of Heinz Redwood, a pharmaceutical industry consultant based in Felixstowe, England, who recently completed a new study, "The Pharmaceutical Industry: Trends, Problems, and Achievements," looking at the industry around the world.

Research and development is the major area of the industry to reflect the escalating costs associated with it. From what Redwood reckons as roughly $500 million spent worldwide on pharmaceutical R&D in 1964, spending reached $7.2 billion by 1983, and probably will be more than $10 billion this year.

In 1964, the U.S. was the biggest spending region, but by 1973, it had been overtaken by Western Europe—$1.01 billion, compared with the $753 million spent by the U.S. pharmaceutical industry. European industry has kept its lead ever since. On a country-by-country basis, however, by 1983 Japan had emerged as the second highest spender, with its industry spending $964 million on R&D, more than the $916 million spent by the pharmaceutical industry in West Germany.

According to Redwood, in the decade to 1983, the long-term trend of a falling U.S. share of pharmaceutical R&D spending worldwide continued. However, despite the increases by Japanese industry, the U.K. had the greatest gain in world share of R&D spending, from 5% in 1973 to 10% in 1983. This he attributes to a series of successful international launches of commercially important compounds from British research, from about 1970 onward, which inspired confidence in further funding.

On the other hand, West German efforts fell off a bit. And Swiss pharmaceutical companies have not been able to match their record from the several decades immediately following World War II.

Redwood analyzed in detail two time spans, 1961–77 and 1981–85. According to industry statistics, U.S. companies were the most innovative in both time spans, but their share of all new drugs introduced around the world increased only from 24% to 25%. Japan, however, undoubtedly benefiting from the increased spending in R&D, jumped ahead of West German companies, who would otherwise have been second to the U.S. West German companies increased their share of new products to 16% from 13%, but Japan jumped from 10% to 22%. France, which had been in second place during the period 1961–77, was particularly beset by extremely tight price controls levied by the French government, and the resulting poor margins eroded its ability to fund new-drug research.

All those new drugs, or new chemical entities, make up a large, often cluttered category. What is more important is the number of those new drugs that become "important," with world sales of more than $20 million, and "leading," those with world sales of more than $100 million.

The British, usually attacked for having fine research but poor marketing, have actually been the most successful country in converting a new drug into an important market—nearly one in three. Redwood attributes this success to good science, a sound approach to selecting new chemical entities, strong developmental capacity, and determination to market globally.

On the other hand, Swiss, West German, and French companies all lost ground in the ranking order of "important" and "leading" products, because they were not strong in antibiotics, one of the top three classes of pharmaceuticals. Antibiotic discoveries and developments were, rather, one of the strong points of the U.S., British, and Japanese pharmaceutical industries.

C&EN staff photo

Redwood: balance of power changing

So far, the Japanese industry remains rather low on the list of countries introducing "important" or "leading" drugs. But, because of the country's strong performance in introducing new drugs, it "would be very surprising" if Japan did not achieve second position in the categories of "important" and possibly "leading" by the 1990s, Redwood predicts. That will be how long it will take the new drugs of the early 1980s to work their way into significant markets around the world.

Where the new, improved drugs first come to market is probably not crucial, given the global character of the business. However, there are significant differences, continuing for the next few years, in where U.S. and European pharmaceutical companies, and Japanese companies, decide to market and conduct R&D.

To a much greater extent, the study points out, U.S. and European companies have elected to become "multinational"—that is, siting major facilities in other countries. The typical pattern: U.S. companies into Europe; companies in European Community countries into other

EC countries; and, less frequently until recently, European companies into the U.S.

And marketing has, of course, gone international. It is the prime means of global penetration by multinationals, says Redwood. Secondhand marketing, through licensees or distributors, can be very successful and may be the only way in which small companies can exploit their product discoveries in large markets such as the U.S. and Japan, he says. But experience throughout the pharmaceutical industry seems to uphold the view that secondhand marketing is second best.

Although Japanese pharmaceutical companies had set up numerous overseas subsidiaries in Asia and Latin America by the mid-1970s, and some in Europe and the U.S. since then, he says, most of these are generally confined to overseeing imports of pharmaceuticals produced in Japan, in technical liaison with local research-based companies. It has only been in this decade, the study says, that Japanese producers have been willing to enter joint ventures with local firms to take Japanese research discoveries through the regulatory phase and, in some cases, into production. And they have begun buying minority stakes in a few foreign pharmaceutical firms.

Multinationals have been exceedingly cautious about investing in Third World countries, because of what they believe are government policies often hostile to the pharmaceutical industry.

Japan leaps into second place as source for new drugs

Nationality of parent company	Number of new chemical entities introduced 1981–85	% of total 1981–85	% of total 1961–77
U.S.	69	25%	24%
Japan	61	22	10
West Germany	45	16	13
Switzerland	23	8	8
Italy	20	7	7
France	19	7	20
U.K.	12	4	6
Scandinavia	7	2	[illegible]
Others	24	9	10
TOTAL	280	100%	100%

Source: Heinz Redwood

Although the Third World takes about 15% of the pharmaceuticals produced in developed countries, multinationals supply about 70% of the Third World's pharmaceuticals. Given that kind of imbalance, the study points out, there are some unpalatable lessons that Third World countries must accept. Although what such countries need are technology and expertise, multinational companies seek profit, and their need to seek it in the Third World is less intensive as long as developed countries remain the focal point of their profitability. The threats to pull out production or investment, if conditions in individual developing countries become too tough, are not idle, the study says. To a large multinational corporation, the market in any individual Third World country is "dispensable," and the Third World is not a politically cohesive bloc capable of concerted retaliation.

Multinationals, Redwood says, "can be cajoled, maneuvered, and shamed into many concessions. They will suffer price controls and freezes, high taxation, the uncertainty of capital repatriation, discrimination in favor of local national companies, ownership restrictions, and other hostile financial and legislative measures, always hoping that 'things will change for the better eventually.' But they will not accept piracy or the forcible transfer of their industrial property." They fear committing core technology to a country that might attempt to wrest it from them while it is still unique. And that, more than anything else, he believes, explains their reluctance to produce intermediates or active ingredients in the Third World, although they are increasingly undertaking such critical production in other developed countries.

Wherever the companies are located, however, the same trends of concentration and lessening opportunity for the second- and third-tier pharmaceutical manufacturers are occurring. Increasingly, just as with the chemical industry, size is the essential requirement.

What Redwood predicts may begin to happen is that large companies with small pharmaceutical segments may well decide to sell what are highly marketable "properties," if the industrial climate continues to favor concentration. Diversified companies with major drug operations, or primarily pharmaceutical companies, on the other hand, will prefer to shed their nonpharmaceutical operations. Even among the leading pharmaceutical companies, however, those that fail to perform effectively and innovatively will lose their independence: Some quite large companies will fall by the wayside.

No giant predators have attempted to enter the pharmaceutical business except through acquisition, because the barriers to entry have been too high, in part professional and in part national. Professionally, the R&D "threshold" and the time span from discovery to breakeven on cash flow are "daunting deterrents." Territorially, national markets differ radically from one another, so that local expertise in every aspect of development and marketing is essential. Even inside the drug industry, latecomers who are not yet established in the leading countries of Europe, or in the U.S. or Japan, mostly must enter them by acquisition; starting from scratch would simply be too slow and risky.

That is true even of novel technologies, such as biotechnology, which sees great promise in the pharmaceutical industry. No one can guarantee, of course, that biotechnology will have changed the face of medicine by the end of the century, as antibiotics did in midcentury, but there must be a chance that it will do just that, the study observes. In terms of scientific advance, and of new products that cannot be produced economically by chemical synthesis or traditional fermentation, the eventual impact could be immense. However, there are already signs that many of the new biotech ventures will never see the light of day as independent profitable commercial firms. Some will fold, some will be taken over by pharmaceutical firms for their scientific expertise, and some will be very successful—which will make them still more attractive to predators. ☐

A12S0-1
9/6/88

SEPTEMBER 5, 1988

CHEMICAL & ENGINEERING

NEWS

05111790098 9 K AR06636SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Biosensors

Using biological components
in analytical probes
Page 24

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 36
CENEAR 66 (36) 1–56
ISSN 0009-2347

SEPTEMBER 5, 1988

News of the Week

- **Researchers have recently reported conflicting results on the new thallium cuprate superconductor materials.** Page 4
- **Environmental impact statements have been published on seven sites being considered by the Department of Energy for construction of the Superconducting Super Collider.** Page 5
- **Results from radiocarbon dating of Shroud of Turin are to be released later this month, amidst rumors that some of the data were prematurely leaked to the press.** Page 5
- **Education Secretary William Bennett has suggested a model science curriculum for elementary schools.** Page 6
- **An Italian ship with a cargo of toxic wastes has been denied port entry at a number of countries in Africa and Europe.** Page 6

Business

Revenues for biotechnology companies continued to increase markedly in the second quarter, although profits remained elusive for most. **Page 9**

Global market for stampable reinforced thermoplastics will grow 24% annually to reach $1.4 billion in year 2000, according to a Kline & Co. study. **Page 10**

Government

Congress is approving boosts in funding for most research programs in fiscal 1989, with NASA leading the way with a 28% increase. **Page 12**

Education

College chemistry course will be offered via satellite TV to rural high schools under program at Oklahoma State University. **Page 15**

Technology

U.K. government funding cuts in Atomic Energy Authority's nuclear reactor research program lead to diversification moves into nonnuclear research areas such as renewable energy, oil and gas engineering, superconductivity. **Page 19**

Cover: Blue crab is one of several natural sources of chemoreceptors for use in biosensors; the micropipet in front of the crab acts as signal-generating element for such an instrument. Photo by Susan Hallowell

Letters 2

Concentrates

Business 7
Government 11
Science/Technology 14

The Departments

Software/Database Update 23
ACS Comment 37
Newscripts 56

Special Report

Biosensors—discrete devices that incorporate biological components into a sensor or probe—represent a novel synthesis of biological and analytical concepts. Applications of biosensor technology are emerging in areas such as medicine, biotechnology, food and agriculture, environmental chemistry, and national defense. **Page 24**

Chemical & Engineering News
1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3–10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 55)

LETTERS

Conversion of methane

SIR: The conversion of methane to ethylene is a very worthy but difficult accomplishment. We wish Madan Bhasin and George Keller (C&EN, July 4, page 22) success.

An alternate possible conversion is the dehydration of ethanol to ethylene. At first glance, the alternate conversion appears preposterous—95% ethanol costing from $1.50 to $2.00 per gal and yielding at the most about 0.5 gal of ethylene (measured as a liquid). However, one patent (U.S. 4,423,270, Dec. 27, 1983) and two papers [Kochar, N. K., et al., *Chem. Eng. Prog.* (June 1981), page 66; and Pearson, D. E., et al., *Ind. Eng. Chem. Prod. Res. Dev.*, **20**, 734 (1981)] have been published, which indicate that 70 to 80% aqueous ethanol may be dehydrated to give very clean ethylene, cleaner than from any dehydrogenation process of ethane.

Moreover, reverse osmosis should allow aqueous ethanol to be separated directly from the fermentation liquor, thus bypassing distillation followed by fractionation of the liquor as is practiced by industry. The price of the reverse osmosis product should be much cheaper and raises the following question: Could dehydration of aqueous ethanol compete with dehydrogenative coupling of methane?

Donald E. Pearson
Professor emeritus, Vanderbilt University

Put chemists in charge

SIR: The future of chemistry and the improvement of the economic status of chemists can be assured by putting chemists in charge of things chemical.

An ACS Comment, "Will chemistry exist in the future?" (C&EN, Dec. 14, 1987, page 51) noted the decline in the quantity and quality of students choosing chemistry as a career. John R. Wasson argued for better quality and fewer numbers of chemists as a means to increase their economic benefits (C&EN, March 21, page 5). Edward J. Johnson answered that (C&EN, June 6, page 3) by suggesting that chemists pursue peripheral fields.

Why should we try to control the supply of chemists for the benefit of an elite few? Why should chemists ply their "trade" outside the chemical profession? There is enough to do in the world of chemistry to require an ever-increasing supply of chemists and at the same time increase their economic return.

This is an era in which chemistry is mistrusted by the public, regardless of the great benefits all enjoy because of developments in the field of chemistry. As I wrote in *The Vortex*, the magazine of the California Section, in October 1986, we chemists have brought on the problem with the products we have created, but the problem is not the products; it is their mishandling. And we in the profession have tolerated the mishandling.

Now, we can rectify this and create many jobs for chemists at the same time. We can follow the lead of other professions and insist that any work involving chemicals or chemically dangerous materials be done by chemists or closely supervised by chemists.

Don't just relegate these responsibilities to an environmental manager at headquarters. The large supermarket products warehouse that has stacks of pool chemicals, pesticides, and kitchen, bathroom, and laundry chemicals, should have a chemist supervising those activities, not a warehouse superintendent who can't even pronounce muriatic. Trucks hauling chemical cargoes should be driven by chemists who understand what they are carrying and how it must be handled. Chemists should replace those in industry who haven't been exposed to any knowledge about the chemicals they use since some chemical salesperson introduced them to the product they are using years ago.

Truck drivers, janitors, dock wallopers, foremen, and others can't practice medicine or law. Why should they be allowed to practice chemistry—i.e., make chemical decisions about the use or handling or disposal of the products they are involved with, knowing little or nothing about them?

Sure, this would change our traditional view of chemists. Some might have to join the teamsters union, for instance. But maybe that high school kid who is teetering about becoming a chemist would gladly become one if he or she could also drive an 18-wheeler.

Chemist truck drivers. Chemist railroadmen. Chemist production supervisors. Chemist warehouse supervisors. It boggles the mind to think of the vast numbers of opportunities that would be available for chemists doing these jobs related to chemicals. And don't say the cost to business would be enormous. I'm talking about putting chemists into jobs that traditionally have paid more than many chemists have been paid.

Best of all, gradually, as these chemists took charge of things chemical, there would be a sharp reduction in

Revenues Continue To Grow at Biotechnology Companies

R&D contracts are still major spur to revenues, although product sales are playing an increasing role; very few firms, however, show profits

Revenues for biotechnology companies continue to grow solidly, but most firms still lack any signs of earnings and, in some cases, losses at the companies almost equal their revenues.

The firms' revenues are still being spurred by increasing R&D contracts, but more and more firms are seeing product sales contributing to the monies they take in. For 20 biotechnology firms surveyed by C&EN, second-quarter revenues totaled $179 million, an increase of 44% from the same period last year. Losses for the companies deepened slightly to a total of $15.9 million from about $15.7 million in the second quarter of 1987.

For the first six months, combined revenues for the 20 companies totaled almost $341 million, up 46% from first-half 1987. Losses at the companies added up to $25.1 million, a decrease from losses of more than $37.2 million in the first six months of last year.

Industry observers expect to see losses grow larger at many of the companies before the industry as a whole begins to turn profitable. This is because the companies are funding clinical trials and other research and development endeavors—a large cash drain necessary for their products to receive the government approval required before their products can enter the marketplace. For instance, at Ribi Immunochem, losses for the quarter deepened to $555,682 from $151,206. Robert E. Ivy, president and chief executive officer of the company, says: "The increased loss reflects our planned acceleration in research and development spending."

Of the 20 companies surveyed by C&EN, only four were profitable in the second quarter. These were industry leader Genentech, plus Am-

Revenues were up 44% for 20 biotechnology companies in second quarter

	SECOND-QUARTER 1988						FIRST-HALF 1988					
	Revenues[a]	Earnings[b]	Change from 1987		Profit margin[c]		Revenues[a]	Earnings[b]	Change from 1987		Profit margin[c]	
	($ millions)		Revenues	Earnings	1988	1987	($ millions)		Revenues	Earnings	1988	1987
Amgen	$ 19.447	$ 0.305	55%	−38%	1.6%	3.9%	$ 34.020	$ 0.793	47%	9%	2.3%	3.1%
Applied Bioscience	11.444	0.929	47	28	8.1	9.3	21.875	1.812	48	35	8.3	9.1
Biogen	7.229	−0.866	172	def	def	def	14.046	−1.801	104	def	def	def
Calgene	5.925	−2.009	−10	def	def	7.6	15.088	−1.965	8	def	def	5.8
California Biotechnology	3.320	−3.512	9	def	def	def	7.680	−5.199	26	def	def	def
Cetus	15.972	−9.372	4	def	def	def	32.582	−16.346	12	def	def	def
Cytogen	1.778	−3.486	−25	def	def	def	3.570	−6.611	−27	def	def	def
DNA Plant Technology	1.495	−0.535	−21	def	def	def	3.035	−0.890	−18	def	def	def
Damon Biotech	1.003	−2.065	−23	def	def	def	2.817	−3.616	10	def	def	def
Ecogen	1.075	−1.247	10	def	def	def	3.116	−1.942	88	def	def	def
Genentech	89.586	15.474	89	194	17.3	11.1	163.710	30.685	90	213	18.7	11.4
Genzyme	6.167	0.120	97	50	1.9	2.6	11.464	0.202	36	52	1.8	1.6
Integrated Genetics	4.224	−0.446	53	def	def	def	7.660	−1.370	24	def	def	def
Liposome	1.169	−1.452	33	def	def	def	2.132	−3.276	22	def	def	def
Molecular Genetics	1.237	−1.058	−73	def	def	def	2.649	−1.442	−61	def	def	def
Monoclonal Antibodies	2.283	−0.740	204	def	def	def	4.098	−2.156	78	def	def	def
Repligen	1.793	−1.050	−70	def	def	50.4	3.796	−2.120	−51	def	def	28.2
Ribi Immunochem	0.301	−0.556	−26	def	def	def	0.640	−1.023	−24	def	def	def
Synergen	2.435	−0.606	18	def	def	def	4.183	−1.786	−1	def	def	0.2
Xoma	1.330	−3.763	−10	def	def	def	2.513	−7.063	68	def	def	def
TOTAL	**$179.213**	**$−15.935**	**44%**	**def**	**def**	**def**	**$340.674**	**$−25.114**	**46%**	**def**	**def**	**def**

a Includes sales, contract research, royalty, and interest revenues. b Excludes extraordinary and nonrecurring items where possible. c After-tax income as a percentage of sales. def = deficit.

gen, Applied Bioscience, and Genzyme.

Genentech, with its sales of tissue plasminogen activator and human growth hormone, posted earnings almost triple those in last year's second quarter to about $15.5 million on an 89% gain in revenues to $89.6 million. For the first six months, Genentech's earnings totaled $30.7 million, up 213% from first-half 1987, and revenues rose 90% to $164 million.

At Amgen, earnings fell 38% in the quarter to $305,000, but revenues climbed 55% to $19.4 million. For the first six months, Amgen's earnings rose 9% to $793,000 on a revenue increase of 47% to $34 million.

Applied Bioscience's earnings for the quarter were up 28% to $929,000 on a sales increase of 47% to $11.4 million. For the half, the company's earnings jumped 35% to $1.81 million on a revenue increase of 48% to $21.9 million.

And Genzyme recorded a 50% increase in quarterly earnings to $120,000 on a revenue rise of 97% to $6.17 million. For the first six months, Genzyme's earnings were up 52% to $202,000, and revenues increased 36% to $11.5 million. Genzyme chairman and chief executive officer Henri A. Termeer says, "Our revenue growth remains on track to exceed $25 million in 1988. With the anticipated launch of [the antibiotic] clindamycin later this year, our profitability should also strengthen." Genzyme is also continuing to broaden its glycoprotein remodeling business. It has signed an agreement with Snow Brands Ltd. of Tokyo to market three new Snow Brand glycoprotein remodeling reagents in the U.S.

Some of the companies had increased product sales during the quarter. For instance at Ribi Immunochem, product sales rose 29% in the second quarter to $130,686. Product sales at Monoclonal Antibodies soared 294% to $2.17 million. Thomas Glaze, chief executive officer, attributes recent sales growth to strong demand for the firm's in-home ovulation prediction test.

Industry observers are predicting a difficult time for many biotechnology firms over the next 12 to 18 months. Roger Shamel, president of Consulting Resources Corp., a Lexington, Mass.-based market research firm, says, "Although promising products are on the horizon, and the industry as a whole is showing signs of growth, biotechnology on an individual company basis, remains a risky business." According to Shamel, financing has become more difficult since the stock market crash last year.

On the expense side of the income statement, Shamel says mounting costs relating to scaleup, patents, and regulations seem to be growing much faster than product revenues. On the legal front, patent lawsuits are heating up.

However, despite the problems, a study done at Consulting Resources concludes that biotechnology is moving into a rapid growth phase. Although the flow of products thus far has been only a trickle, the rate of introduction will increase dramatically in the next few years.

William Storck

Stampable plastics use to grow 24% annually

By the end of this century, the worldwide market for stampable reinforced thermoplastic sheet is forecast to grow to about $1.4 billion, a 24% average annual rate over the 1987 level of $80 million, according to market researchers Kline & Co.

Stampable reinforced thermoplastics are high-performance materials adaptable to many semistructural and structural applications. The incorporation of fiber reinforcements yields low-cost, high-performance composites. According to the Passaic, N.J.-based firm, stamping technology has been applied to all thermoplastics from commodities to engineering resins to highly heat-resistant materials.

According to a Kline study, the technology was pioneered in the U.S. by PPG Industries with its Azdel brand polypropylene sheet. Two years ago, PPG formed a joint venture, Azdel Inc., with General Electric to exploit the technology with new base resins for new uses.

The study says that overseas activity has been even greater with four major European suppliers active in thermoplastic composites. These include Shell, BASF, Exxon, and Chemie Linz. Other European companies have programs in developmental stages.

In Japan, two companies have licensed the original PPG technology and others are developing new products internally.

According to Kline, recent market and technological developments are expected to fuel dramatic growth through the year 2000 when worldwide consumption of stampable sheet is expected to reach 1 billion lb. An increased range of applications will result from new resins, higher reinforcement levels, improved processing techniques, and more emphasis on suppliers. Other factors fueling the growth include a varied group of reinforcement types, an expanding range of substrate resins, new production processes being developed, increasing productivity, and the development of class-A finish parts using mineral fillers, varying reinforcements, metal-cladding technology, and complementary processing techniques.

In addition, the study says, more than 18 major organizations worldwide have active research programs in the area. Among these, apart from the PPG-GE joint venture, Akzo and Isosport have a cooperative agreement; Du Pont, Chemie Linz, Eastman Kodak, Himont, and Dow Chemical are developing processes internally; Exxon has acquired technology developed by Japan's Arjomari; and Shell has acquired Symalit, which Kline calls Europe's leading supplier.

Several types of firms are capitalizing on the growth trend. Resin suppliers are using the technology to increase material performance, opening up new uses; fiber reinforcement and mineral suppliers are offering products tailor-made for use in thermoplastic composites; sheet molding compound molders and metal stampers are broadening their business scope and protecting key business areas. And, Kline says, equipment makers must provide customized and fully automated systems to ensure the upward growth.

William Storck

Congress Approving Increases for Most R&D Programs in Fiscal '89

Research funding hikes range from 5% for the Department of Energy to 28% for NASA; in between are increases for NSF, 9%, and EPA, 8%

Janice R. Long, C&EN Washington

Congress is well on its way to accomplishing a feat it hasn't been able to achieve in the past half dozen years or so—enactment of all 13 of the fiscal 1989 appropriation bills before the current fiscal year expires on Sept. 30. Two appropriation bills have been signed into law. Conference reports have been filed on two others. Final versions of the remaining nine are being worked on by House-Senate conference committees and likely will be completed well before Oct. 1. Research budgets, so far, are holding up quite well in a year when there wasn't supposed to be much room for increased funding.

The bill that has been signed into law is H.R. 4567, the Energy and Water Development Appropriation Bill, 1989, which funds almost all of the Department of Energy's research programs. The two exceptions are the fossil and conservation R&D programs, which are funded under H.R. 4867, the Department of Interior and Related Agencies bill that has been cleared by a conference committee.

Taken together, the two bills provide $4.8 billion for DOE R&D programs in fiscal 1989. That is an increase of just 5% over current funding levels and the lowest R&D increase allowed by Congress to date. And not all of DOE's research programs are getting even that much of an increase. For example, funding for basic energy sciences is set at $552 million, a decrease of 2% from the current funding level. Within that category the budget for operating expenses for the chemical science program is set at $135 million, up 3%, and that for materials sciences at $181 million, up 5%.

In contrast to the fiscal 1988 appropriation, which funded 10 specific university research projects out of the basic energy sciences budget, this year's bill specifies funding for only four projects: $13 million for the Center for Advanced Microstructure & Devices, Louisiana State University; $11.1 million for Loma Linda Medical Center in California; $10 million for the Barry Goldwater Center for Sciences & Engineering, Arizona State University; and $5.5 million for the Center for Automated Technology at Drexel University.

Congress provided only $100 million of the $316 million the Administration requested for the Superconducting Super Collider. Of the funds it did provide, $16 million is allocated for capital equipment needed to support the R&D effort and $84 million is for operating expenses, R&D, preliminary engineering and design, and site selection activities. Construction work is specifically prohibited.

Congress increased funding for DOE's university research support programs 38% to $22 million. However, it earmarked $6 million, or over 25%, of the money for university nuclear engineering programs and held funding for university research instrumentation grants constant at $5 million.

The other bill that has been signed is H.R. 4800, Department of Housing & Urban Development—Independent Agencies Appropriation Bill, 1989. That bill provides funding for, among others, the National Aeronautics & Space Administration, the National Science Foundation, and the Environmental Protection Agency.

NASA is undoubtedly the big winner in this bill. Its overall budget is up 21% to $10.7 billion, and its research budget is up 28% to $4.2 billion. The bill provides the full $900 million requested by the Administration for the space station. However, only half of that funding will be available for the agency to spend on Oct. 1. The rest will become available on May 15, 1989, unless the new President notifies Congress by Feb. 1 that he doesn't want any more money spent on the space station.

In addition, the NASA Administrator is given authority to transfer up to $30 million from the $290 million facilities account to the research budget. Of that amount, $10 million is to be spent on planetary programs and up to $10 million on the "scatterometer" instrument. Congress itself transferred $15 million from the facilities account into a "Science, Space & Technology Education Trust Fund." The money is to be invested in U.S. Treasury special issue securities, and the interest will be used to fund education improvement grants.

NSF did not fare so well as NASA. Still, its overall budget is up 10% to $1.9 billion, with funding for research and related activities up 9% to $1.6 billion. The conferees directed that the $20 million reduction from the budget request be applied equally across all disciplines except for ocean sciences and astronomical sciences, which are to receive the requested amount. In addition, the conferees expect NSF to provide the full $54 million requested for the five national supercomputing centers; to provide $1.5 million for computing capabilities not available at those centers; to spend up to $3 million to support enhanced research efforts in ocean engineering; and to provide $900,000 to the International Institute for Applied Systems Analysis and $200,000 for the Cajun Pass drilling project.

Congress did not approve NSF's five-year, $150 million request for a new science and technology centers program, though it did not prohibit funding the centers out of existing funds. No such awards are to be made, however, until Congress approves NSF's fiscal 1989 operating plan. Funding for science education is up 23% to $171 million, with a minimum of $1 million to be used to support curriculum development programs for elementary and junior high schools. The conferees also accepted a Senate provision limiting the pay of principal investigators and others supported by NSF funds to $95,000 per year. The Senate report on the bill noted that some individuals were being paid as much as $135,000 a year.

Congress is fairly generous in setting 1989 R&D budgets

$ Millions	1989 Congressional appropriation	1989 Administration request	1988 appropriation	% change Appropriation vs. request	% change Appropriation vs. 1988
NASA	$10,701.0	$11,488.0	$ 8,856.5	−7%	21%
Space flight, control, and data communication	4,364.2	4,841.2	3,908.3	−10	12
R&D	4,191.7	4,446.7	3,274.2	−6	28
Research & program management	1,855.0	1,915.0	1,495.7	−3	24
Facilities	290.1	285.1	178.3	2	63
NIH	**7,158.9**	**7,123.2**	**6,766.6**	**7**	**6**
National Institutes	**6,570.9**	**6,588.5**	**6,181.8**	**0**	**6**
Cancer	1,574.4	1,593.5	1,469.3	−1	7
Heart, Lung & Blood	1,046.6	1,054.5	965.5	−1	8
Allergy & Infectious Diseases	745.0	745.4	638.8	0	17
General Medical Sciences	682.4	687.8	632.7	−1	8
Neurological & Communicative Disorders & Stroke	567.1	571.0	534.7	−1	6
Diabetes, Digestive & Kidney Diseases	560.4	565.9	534.7	−1	5
Child Health & Human Development	426.2	418.4	396.8	2	7
Eye	231.4	234.0	324.9	−1	3
Environmental Health Sciences	223.5	223.2	215.7	0	4
Aging	222.9	205.2	194.7	9	14
Arthritis & Musculoskeletal & Skin Diseases	160.0	158.9	147.7	1	8
Dental Research	131.0	130.7	126.3	0	4
Research Resources	**358.6**	**358.0**	**368.1**	**6**	**−3**
Other	**229.4**	**176.4**	**216.7**	**30**	**6**
ENERGY R&D	**4,800.6**	**4,721.8**	**4,576.8**	**2**	**5**
Weapons R&D, testing	1,487.0	1,465.5	1,466.9	1	1
General science and research	922.0	1,197.1	810.4	−23	14
Supporting research and technical analysis	642.2	611.8	648.5	5	−1
Nuclear	352.7	351.9	347.0	0	2
Fossil R&D	380.6	167.0	327.0	127	16
Fusion	351.5	360.0	335.0	−2	5
Environmental, biological activities	350.0	359.0	338.2	−3	3
Renewable energy source	148.9	123.2	147.6	20	1
Conservation R&D	165.7	86.3	156.2	92	6
NSF	**1,885.0**	**2,050.0**	**1,717.0**	**−8**	**10**
Research and related activities	1,583.0	1,603.0	1,453.0	−1	9
Science education	171.0	156.0	139.2	10	23
Antarctic program	131.0	141.0	124.8	−7	5
Science and technology centers	0	150.0	0	—	—
EPA R&D	**378.9**	**374.8**	**352.2**	**1**	**8**
TOTAL	**$24,924.4**	**$25,757.8**	**$22,269.1**	**−3%**	**12%**

Note: All numbers are estimates. **Source:** Congressional reports

For EPA, its intra- and extramural research budget is up 8% to just under $380 million. It includes $2 million to be matched on a 50-50 basis by private contributions for asbestos research; $2.6 million for research on waste minimization and pollution prevention; $500,000 for a cumulus clouds acid rain study at the University of North Dakota; and $450,000 for completion of the Kanawha Valley, W.Va., health effects study.

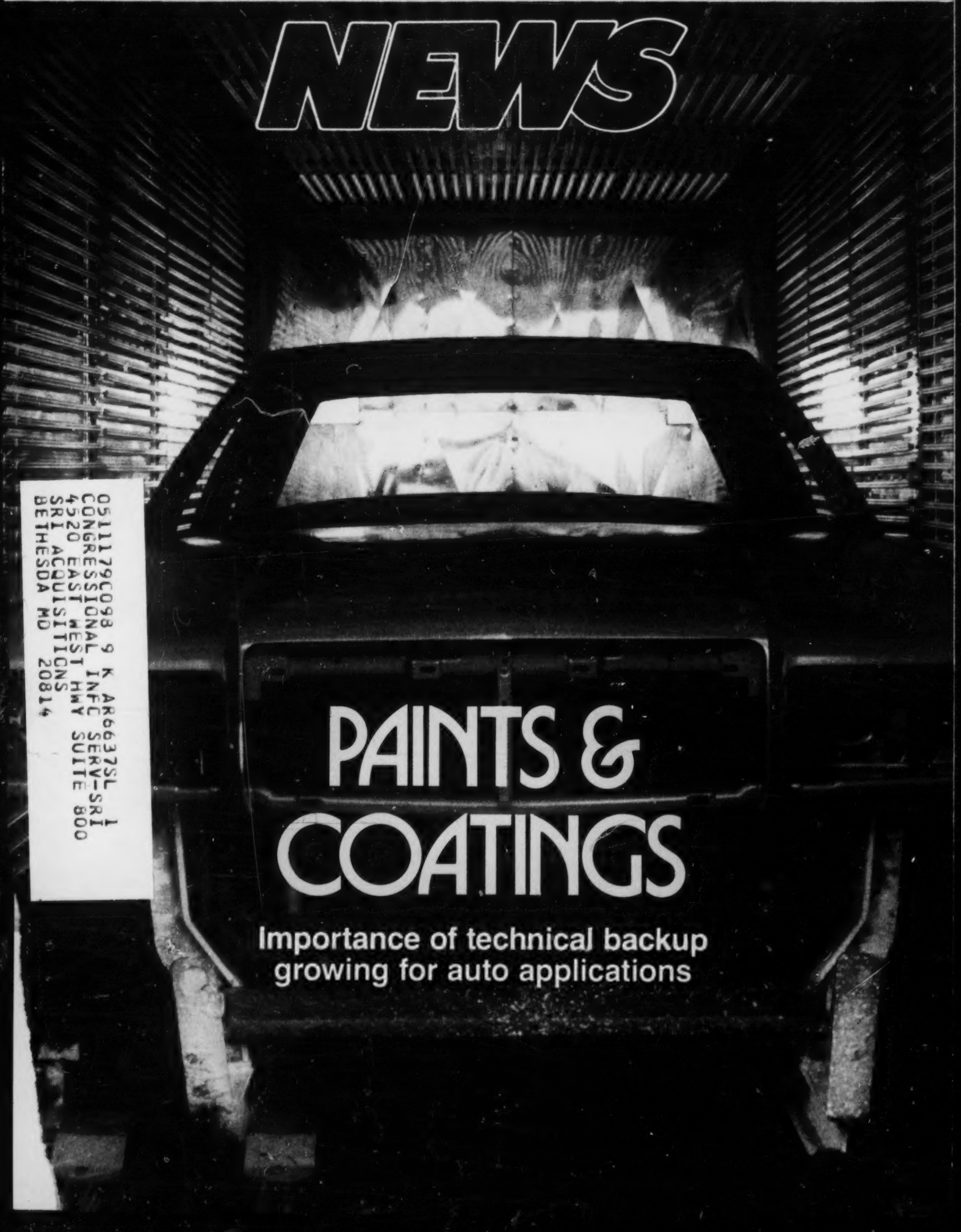
One of the first items of business when Congress returns this week from the August recess will be approval of the conference report on H.R. 4783, Departments of Labor, Health & Human Services, and Education, and Related Agencies Appropriations Bill, 1989. Congress has approved a 6%, $840 million increase to $7 billion for the National Institutes of Health. That amount includes a 30%, $39 million increase to $607 million for acquired immune deficiency syndrome (AIDS) research.

The budget for the National Institute of General Medical Sciences includes funding for the establishment of a new biotechnology-based research training program focused on the applications of engineering, physics, chemistry, mathematics, and biology to the interdisciplinary research needs of the emerging U.S. biotechnology industry. The NIH director's budget includes $14 million for research centers in minority institutions and money to support an additional 200 positions for AIDS research and an additional 150 positions for non-AIDS activities. And when President Reagan signs the legislation setting up a new Institute on Deafness & Other Communication Disorders, it will start out with a $96.1 million budget. The money will come out of funding approved for the current National Institute of Neurological & Communicative Disorders & Stroke, whose name will then be changed to the National Institute of Neurological Disorders & Stroke. ☐

A1250-1
9/14/88

SEPTEMBER 12, 1988

CHEMICAL & ENGINEERING NEWS



PAINTS & COATINGS

Importance of technical backup growing for auto applications

0511179C098 9 K AR6637SL 1
CONGRESSIONAL INFC SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

CHEMICAL & ENGINEERING NEWS

Volume 66, Number 37
CENEAR 66 (37) 1-120
ISSN 0009-2347

SEPTEMBER 12, 1988

News of the Week

- **In technology policy report aspiring to influence election debate, the Council on Competitiveness of Washington, D.C., urges improved national policy to help industry perform better in global competition. Page 4**
- **Occupational Safety & Health Administration rebuts charges of lax enforcement. Page 5**
- **Dow Chemical works out merger agreement with Essex Chemical, rescuing Essex from a possible hostile takeover by Gurit-Heberlein. Page 5**
- **Breaking with tradition, England's Oxford University launches two private-sector initiatives. Page 6**
- **British researchers are successful in fabricating polyacetylene semiconductor devices. Page 6**

Cover: Combination convection/medium-wave infrared oven for drying auto coatings at Du Pont's Finishes Applications Lab in Troy, Mich.

Letters 2
Editor's Page 3

Concentrates
Business 9
Government 17
Science/Technology 24

The Departments
New Products 32
ACS News 84
Meetings 91
Newscripts 120

Business

Canadian chemical industry is chalking up a banner year, but signs of economic problems ahead could indicate trouble for the industry. **Page 13**

Government

EPA ban on construction of air polluting sources in Los Angeles area is empty gesture in city that has tight controls on carbon monoxide and ozone emissions. **Page 19**

Final site selection for the Superconducting Super Collider can now proceed after Department of Energy's release, last month, of draft environmental impact statement for the project. **Page 21**

Technology

New AutoSpec double-focusing mass spectrometer from VG Analytical incorporates automation features that ease operation for nonexpert users. **Page 25**

In Stockholm to deliver a plenary lecture at a carbohydrate conference, chemist also performs organ recital at a local church. **Page 26**

Four new engineering research centers approved by National Science Board have chemistry components. **Page 29**

Books

"Nuclear Imperatives and Public Trust," by Luther J. Carter, confronts events and politics leading to nuclear waste problems and solutions that face noncommunist countries. **Page 81**

Product Report

As paints and coatings sales hit new highs, focus by major producers is on technical applications labs to better service the lucrative auto market and on performance paint materials. Page 37

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Ann M. Thayer (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 119)

LETTERS

Attracting chemistry students

SIR: In response to the national trend toward fewer science majors, our department continuously strives to attract students to chemistry. One of the most successful efforts in this regard has been a one-day chemistry symposium for high school seniors. I pass along this information, hoping that it can be helpful to other chemistry departments.

The symposium was held in conjunction with Colgate's annual "subfrosh" weekend, where students of all interests spend a Sunday and Monday in April visiting the campus as a group. Our program began Saturday morning with a welcoming reception and tours of our laboratories. Next came a discussion of the chemistry curriculum at Colgate and the possible careers stemming from a chemistry major. After lunch with Colgate's present chemistry majors, the visitors got some hands-on experience using our equipment and computers while performing an experiment that spectrophotometrically determines the phosphate content of soft drinks. The rest of the afternoon was spent discussing current chemistry research at Colgate with our chemistry majors. Our research students prepared posters depicting their undergraduate projects. The high school seniors had dinner with the chemistry faculty followed by an informal gathering at the chairman's home.

The success of this day is already evident. Of the high school students who participated, two thirds will attend Colgate this fall. Their familiarity with our department and faculty will certainly have a positive impact on our enrollments.

I encourage secondary school teachers interested in our program to contact me.

Carla M. Verschoor
Assistant Professor of Chemistry
Colgate University

General chemistry texts

SIR: Recently, a number of my colleagues and I who are responsible for teaching general chemistry at Adelphi University went through the ritual of choosing a new chemistry text. We were overwhelmed by the extraordinary production that went into the new crop of general chemistry texts. They are all four-color (or all color given the shadings available), make copious use of color plates, have breathtaking drawings, wonderful photographs, and all together comprise a book of some 25 chapters.

The written page is no longer simple. There are inserts, sidebars, boldface, italics, and examples peppered throughout. At the end of each chapter there are some 50 problems along with a glossary of important new words, a summary of the important highlights of the chapter, and definitions of those words that were defined in the body of the chapter. But this is not all. Bundled with each text is a multitude of accessories. We may find: lab manual, study guide for students (answer book), test bank, overheads, instructor's guide to text, instructor's guide to lab manual, test bank on software, and video.

And now to the heart of the matter—the textbook. It is clearly overproduced. It would be more fitting to spend its time as a coffee table ornament than a chemistry text. The colors, the plates, the extras, the gimmicks, the overburdening wealth of material, is too, too much. I could list some 20 topics and more than five chapters that can easily be omitted. I'm sure most teachers can do the same.

The whole package has become unconscionably wasteful and pedagogically unnecessary. Are the publishers solely to blame? Each publishing house must keep up with what is being presented by the competition or risk losing adoptions. I've been told that a publishing house must commit approximately a half million dollars to do a general chemistry text. A one-book failure could easily bankrupt a small- to medium-size company. What are the consequences of this reality?

Publishers will only publish a book that they truly believe will be a best-seller. This means that unknown authors will probably be rejected. Any manuscript that one publisher rejects will be labeled with a bad history. Innovations in presentation style, ordering of topics, along with any revolutionary thoughts in general chemistry teaching, have almost a zero probability of being published. The publishers need a sure thing to protect their investment.

We cannot look to the publishers to change. We are the consumers and it is up to us to ask them to publish texts that are reasonable in length, cover those topics that should be taught in general chemistry (not elementary physical chemistry, not organic chemistry, not biochemistry, not a beginner's course in environmental chemistry, and so on), uncluttered and devoid of those wasteful additions to the package.

Stanley Windwer
Professor of Chemistry
Adelphi University

Canadian Chemical Industry Enjoying Banner Year

But a stronger Canadian dollar, rising interest rates, and a possible slowing of economic growth could spell trouble ahead for the industry

The Canadian chemical industry is well on its way to chalking up a banner year. Production and shipments are up. Exports are strong. Sales are booming. Buoyed by higher selling prices, earnings are in many cases at record levels (C&EN, August 22, page 13).

With shortages in many key chemicals, Canadian chemical companies are hitting the expansion trail in force. Ethylene, styrene and polystyrene, sodium chlorate, hydrogen peroxide—even nitrogen fertilizer—are some of the many chemicals that are already ticketed or at least being considered for expansion projects.

In a recent report, Alberta's Energy Resources Conservation Board (ERCB) says that new investment in the province's petrochemical industry could top $2 billion (Canadian, 1971 dollars) by the year 2002. That's about $1.6 billion (U.S.) at current exchange rates. Major projects, says ERCB, would include ethylene, methanol, and possibly ammonia.

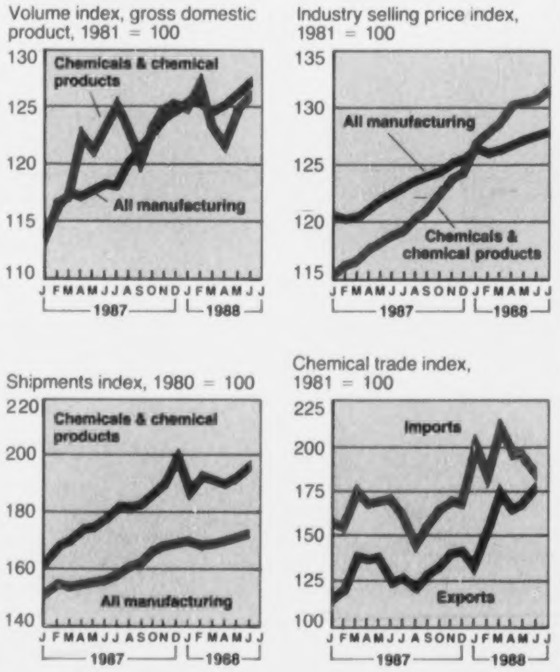
But a growing number of experts, both inside and outside the industry, are concerned that the Canadian chemical industry may be in danger of repeating its major mistake of the early eighties—adding new capacity at exactly the wrong time. Three things are triggering this concern. One is a strengthening Canadian dollar. Another is rising interest rates. And the third is the very real possibility that the six-year binge of economic growth will either grind to a halt or, more likely, at least slow down.

Methanol is the big gainer

Production, thousands of metric tons	1987	First five months 1988	First five months 1987	% change 1987-88
ORGANICS				
Benzene	720	304	313	−2.7%
Butadiene	167	74	71	4.3
Ethylene	2140	970	888	9.2
Formaldehyde	122	48	53	−9.4
Methanol	1627	887	625	42.2
Propylene	628	260	260	0
Toluene	396	176	168	5.1
Xylene	345	193	137	40.8
PLASTICS				
Polyethylene, low density	1021	468	424	10.5
Polyethylene, high density	269	140	113	23.9
Polyesters, unsaturated	47	19	19	0
INORGANICS				
Hydrochloric acid	164	71	64	11.8
Nitric acid	900	376	441	−14.6
Phosphoric acid[a]	464	205	223	−8.4
Sulfuric acid	3437	1636	1613	1.5
Ammonia, anhydrous	3512	1747	1547	13.0
Ammonium phosphate	941	426	467	−8.7
Chlorine	1635	692	672	3.0
Sodium hydroxide	1770	765	737	3.9

a 100% P_2O_5. Source: Statistics Canada

Chemical shipments, exports, and prices all rise



Source: Statistics Canada

Blaze new trails with cyclo-dextrins. Or follow the tracks of those who do.

Cyclo-dextrins can be described many ways: Cyclic clathrates...Natural ligands...Separation agents... Transport agents.

But there's just one way for your company and your products to go with cyclo-dextrins—Up!

These novel molecules can modify and stabilize highly active compounds, phase transfer, protect, shield, or catalyze.

Imagine nitroglycerin that won't explode! Or control of garlic breath. Colors and pigments more fade-proof. Fragrant fabrics.

Imagine what *you* could do with these intriguing molecules in your hands. Alert scientists are already finding new opportunities, making more creative and important contributions, extending their own knowledge as they extend cyclo-dextrins' range of applications.

Proven applications include photochemistry and electronic chemicals, pharmaceuticals, agricultural chemicals, food, and personal care. Cyclo-dextrins' real magic is that *nobody really knows the limits of their potential!*

Cyclo-dextrins belong in your hands today. All you have to do is call American Maize, *the only cyclo-dextrin producer in America.*

The choice is yours: take the lead and call us today...or follow the competitor who did.

American Maize-Products Company,
Corn Processing Division.
Call Toll-Free 1-800/348-9896.
In Indiana, call 1-800/552-9793.

AMAIZO
American Maize-Products Company

Amaizo—Dedicated To Your Success.

CIRCLE 87 ON READER SERVICE CARD

© 1988

Paul H. Williams, president of Celanese Canada, warns that if the Canadian dollar continues to strengthen, his company's export prices could be hurt. That means that profits also would be affected. The reason, of course, is that a stronger currency makes exports more expensive and less competitive in international markets. Conversely, it makes imports less expensive and more competitive in the country's domestic markets.

Williams' concern should extend well beyond his own company, because exports are critical to many companies in the Canadian chemical industry. Many of the world-scale petrochemical plants built in the country depend on exports for well over half of their sales.

Despite the stronger Canadian dollar, Canadian chemical exports are up a hefty 31% through the first half of the year. Imports, meanwhile, are running only 21% higher. If the first-half trend continues, Canadian chemical exports could hit $6.6 billion (U.S.) this year and turn the country's chemical trade deficit into a surplus.

However, if the Canadian dollar continues to strengthen as it has, that possibility could be aborted. Last month, the Canadian dollar's average value against the U.S. dollar was 81.7 cents. At the start of the year, it was only 77.9 cents. A year ago, it was 75.5 cents, and not very many years ago the Canadian dollar was equal to only 72 U.S. cents.

Canadian chemical exports have surged despite the stronger Canadian dollar because overseas demand for petrochemicals has been so strong. Now many wonder how long the world's economies can sustain that demand level.

They wonder, too, about the Canadian economy. It has been robust this year, with growth pegged between 3.5 and 4.0%. But, as in the U.S., strong economic growth unleashes inflation fears—and inflation fears trigger higher interest rates. To round out the cycle, higher interest rates put a damper on economic growth.

Last month, the prime rate in Canada rose to 11.25% from 10.75%. Many Canadian economists think that it will go higher still, if not this year, then certainly sometime next year. These higher rates could have a twofold impact on Canadian chemical companies. First, they could decelerate economic growth. Estimates of Canadian economic growth in 1989 center around 2.1 to 2.2%. That would mean less demand for chemicals. Couple that with the lower demand expected in export markets and the result would be less chemical sales and lower chemical profits.

The other impact of higher interest rates is stiffer costs on the debt burden needed to finance planned expansions. Canadian chemical companies got badly burned in the early 1980s when interest rates soared and markets collapsed.

Remembering those costly lessons, balance sheets of most Canadian chemical companies are in much better shape now than they were then. As a result, they may be better able to cope with rising interest rates than they were in the early eighties. So far, at least, the industry leaders don't appear to be worried about their expansion plans or the prospects of weaker markets. Some say they should be.

Meanwhile, existing plants are running at or near full capacity. As they have for several years, ethylene and its derivatives continue to sport healthy growth rates. Through the first five months of the year, ethylene output was 2.1 million metric tons, 9.2% higher than in last year's corresponding period. Low-density polyethylene output was up 10.5%, and that of its high-density counterpart was a whopping 24% higher.

Output of methanol, which has had more than its share of problems over the past few years, is ahead of last year's pace by a staggering 42%. And fertilizers, whose markets also have been depressed, are also staging a comeback. Ammonia production, which has declined for the past two years, was 13% higher through the first five months. And urea output was up almost 15%. Even sulfuric acid output, which has been dropping since 1984, was higher this year, if only by 1.5%.

Earl Anderson

BASF photo

Paint Sales at 10-Year Peak

Marc S. Reisch,
C&EN Northeast News Bureau

Record demand for paints and coatings pushed shipments beyond 1 billion gal last year, making it by far the best year for this industry in terms of volume since 1977. The value of shipments also peaked at over $10 billion, and industry executives believe that 1988 could be an even better year.

This three-part article examines the general U.S. paint market depicted by government figures, the U.S. automotive paint industry, and high-performance coatings.

Beginning on page 38, U.S. government figures not only portray the size of the market, but show where demand for coatings appears to be strongest. Not surprisingly, the increased demand for product coatings in the face of a weaker U.S. dollar has made U.S.-produced industrial goods competitive again in the world market.

Beginning on page 48, the huge market for paints in the auto industry is explored. Although auto production has not benefited from increased overseas demand to any great degree, there is a potential for that to happen in the future. Some see a better automotive production market ahead in light of Honda's exports of passenger cars from its Marysville, Ohio, facility. They find added significance in the number of Japanese auto makers who are setting up assembly lines in the U.S. Should the U.S. significantly increase auto production, paint manufacturers such as Du Pont, PPG Industries, and BASF—the three largest U.S. producers—would benefit.

The automotive market today remains a highly competitive one. It is a market driven not only by changes in chemistry but also by the demands of auto makers who want the best corrosion protection and the most appealing finishes they can acquire for their car lines. In a world where car production capacity is higher than real demand, paint is one element that auto makers can use to gain the market share each needs to survive.

To meet the demand, the Big Three paint makers are investing in technical applications labs to service the auto industry like they never have before. The investments are in the millions of dollars, and are considered pivotal not only in helping Detroit but in helping world auto makers achieve better-quality finishes with lower volatile organic chemical (VOC) emissions. The paint producers consider the investments pivotal in their own quest for greater share of market, too.

Beginning on page 79, performance paint materials are highlighted. One major innovation is a new fluoropolymers coating technology that allows chemical process vessels to operate smoothly and efficiently under some of the most adverse conditions.

Shipments continue to rise

U.S. manufacturers shipped slightly more than 1 billion gal of paints and coatings in 1987, according to the Department of Commerce. That volume of shipments marked a 1.7% increase over the previous year's shipments and marked a 10-year high for the industry. The last time paint, varnish, and lacquer production exceeded 1 billion gal in the past 17 years was in 1978.

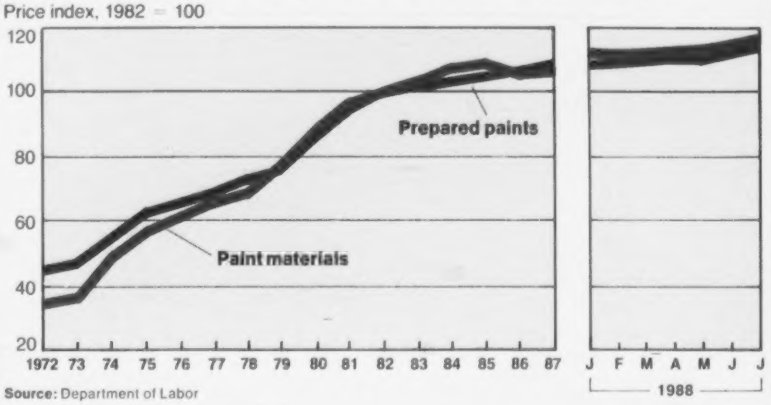
Even better news for paint manufacturers: The value of all paints and coatings shipments in 1987 reached $10.2 billion. That sales figure is 7.4% higher than in 1986.

Higher-value paints sold into all three major market categories—architectural coatings, product coatings, and special-purpose coatings—account in large measure for the growth in value in excess of shipments.

The good news should not have come as a surprise to those close to the industry. The strength of the economy overall and the recent resurgence of heavy industry have helped fuel the demand for more paints and coatings.

In addition, the decline in the value of the dollar relative to most major foreign currencies has helped make U.S. merchandise more competitive worldwide and thus has helped fuel sales of product coatings in particular. Conversely, the weakness in the dollar has slowed the demand for imported products, thereby increasing market share for U.S.-made durable goods.

Rise in paint materials prices is outpacing that of paint

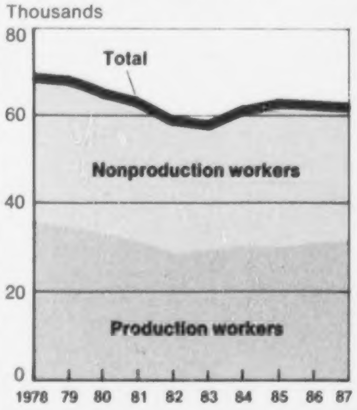


Source: Department of Labor

U.S. paint makers have been the beneficiaries of the improved market performance of domestic manufacturers. Although 35%, or 350 million gal, of domestic paint shipments were designated for the product coatings category in 1986, 36%, or 360 million gal, of all shipments went into the product coatings category in 1987. Shipments of paint within the product coatings segment, which includes automotive finishes, grew at a faster rate—2.9%—than for all paints and coatings.

More recent figures for the first quarter of 1988 indicate that the year as a whole promises to be better than 1987. Shipments were up 4.2% to 244 million gal for the first three months of 1988 compared with

Paint production worker employment up again



Source: Department of Labor

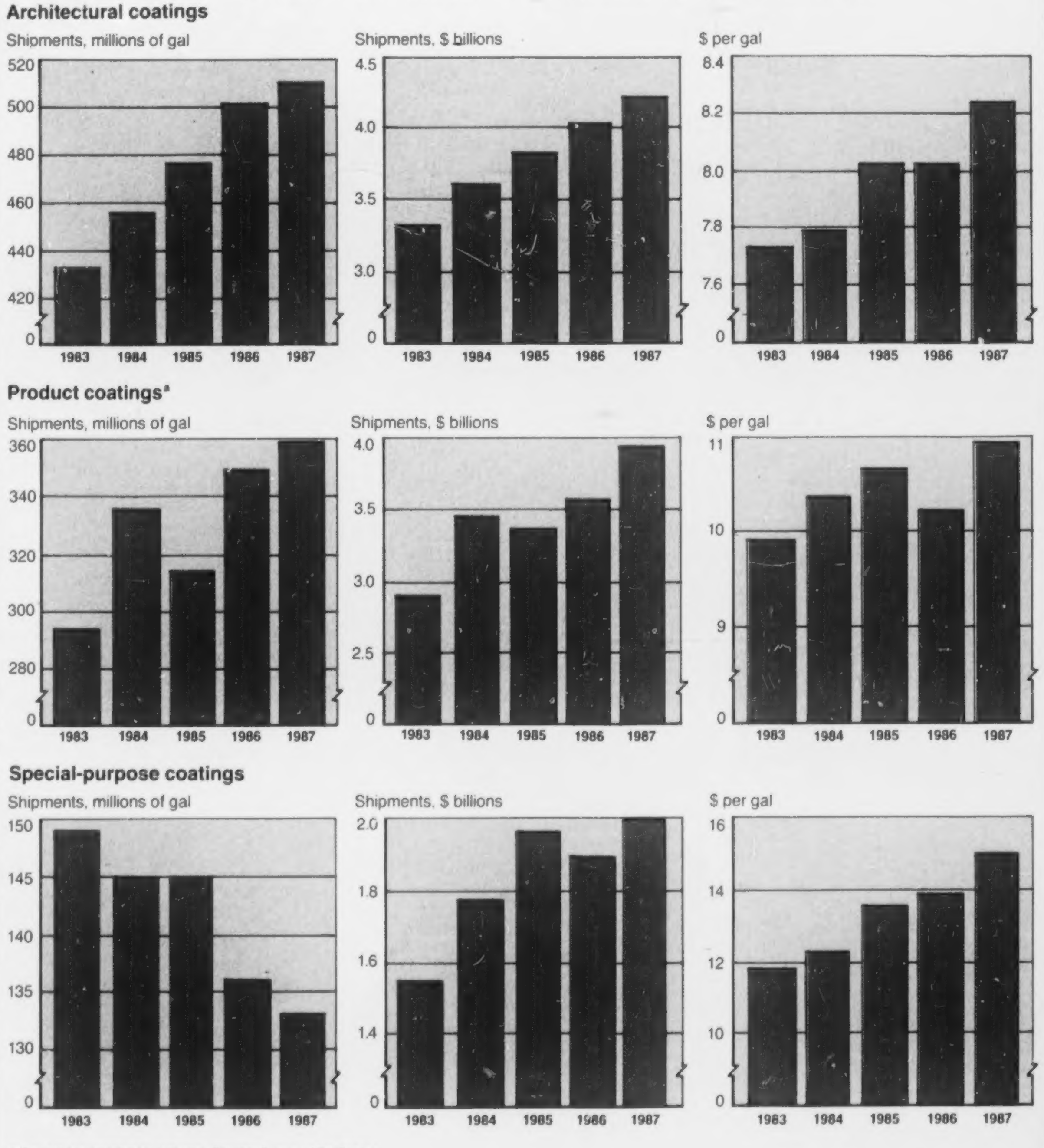
Three main paint categories break down this way

Architectural coatings
- Exterior house paints
- Interior house paints
- Undercoaters, primers & sealers
- Stains

Product coatings[a]
- Wood furniture & fixtures
- Automotive
- Metal containers
- Machinery & equipment
- Factory-finished wood
- Metal furniture & fixtures
- Sheet, strip & coil
- Nonautomotive transportation
- Appliances
- Electrical insulation
- Marine
- Film, paper & foil
- Pipe
- Toys & sporting goods
- Miscellaneous consumer & industrial products

Special-purpose coatings
- Automotive & machinery refinishing
- High-performance maintenance
- Traffic paint
- Roof coatings
- Bridge maintenance
- Aerosols
- Swimming pool coatings
- Arts & crafts
- Metallic coatings
- Multicolored coatings

[a] Original equipment manufacturers **Source:** SRI International



Prices rise in all categories, shipments up for architectural, product coatings

a Original equipment manufacturers. **Source:** Bureau of the Census

the same period last year. Shipments also increased in each of the major categories during the first three months of this year. Shipments of architectural coatings, at 118 million gal, were 3.0% ahead of the same period in 1987; product coatings increased 2.5% to 92 million gal; and special-purpose coatings grew at a much higher than usual rate of 14% to 34 million gal.

The value of paint shipments for the first three months of 1988 also increased. The government figures show that the cumulative value of shipments in the first quarter of this year was up 13% from last year's first quarter to $2.6 billion. Architectural coatings increased in value 4.2% to $959 million. The value of product coatings increased almost 15% to $1.1 billion, and the value for special-purpose coatings increased 12% to $492 million.

The paint market remains a highly cyclical market dependent in large measure on the overall economy, and government data indicate that the economy has continued to be strong during the first part of 1988. Gross national product, seasonally adjusted, was up 5.1% in constant dollars during the first quarter of 1988 from the fourth quarter of 1987. Most observers remain confident that 1988 will be a good year for industrial growth, though they remain cautious in their predictions following the Presidential elections this November.

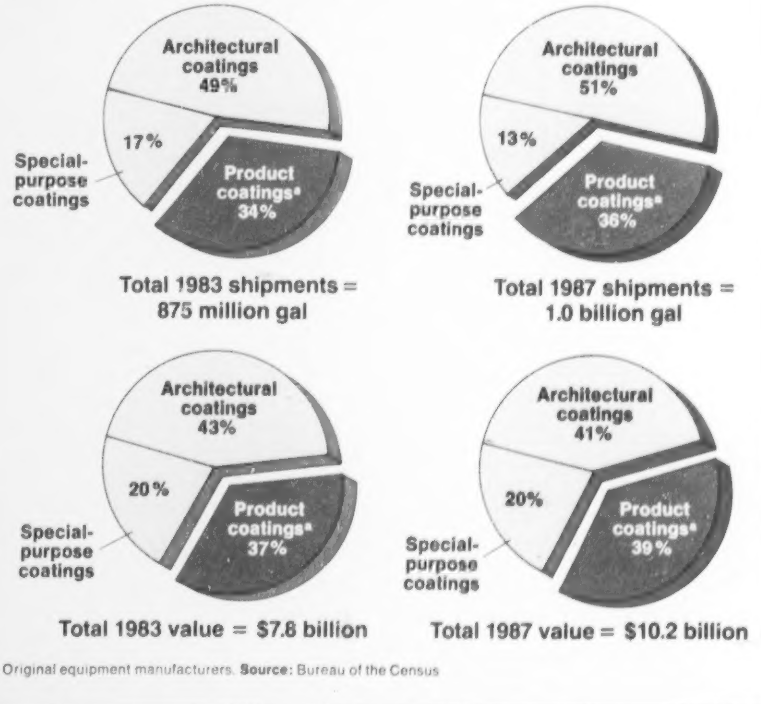
Industry analysts predict that 1988 will be a good year overall for the paint industry. James A. Rauch, president of Rauch Associates, Bridgewater, N.J., forecasts slow but steady growth for the industry, though he notes that use of decorative powder coatings is growing faster than the industry as a whole. However, he points out that powder coatings are a very small segment of the overall market.

Jeffrey Back, project manager for industry analyst Kline & Co., says the product coatings market for original equipment manufacturers (OEM) is now positioned for the strongest growth, in part because of the many foreign-based auto makers setting up manufacturing sites in the U.S. However, architectural coatings markets will soften, says Back, mostly because of a slowdown in housing and office construction.

Within the special-purpose coatings category, plant and equipment maintenance coatings may not be so strong a market in 1988 as it has been in the past few years. Companies have not only kept up maintenance schedules on existing plants, they have accelerated maintenance programs because they were flush with cash, explains Back. As a result, Back expects the maintenance segment to lag for the next year or two.

Bridge coatings, also included under the special-purpose category, have not been as strong a market as much of the recent talk concerning rebuilding decaying inner city bridges would indicate. Although a few dilapidated bridges have been the subject of national discussion, such as New York City's decaying Williamsburg Bridge or the collapsed Mianus River Bridge on the Connecticut Turnpike, there has been no real discernible increase in money spent on bridge maintenance, says Back. The industry is still waiting, he says.

Product coatings grow in both shipments and value, although architectural uses remain the leader



[a] Original equipment manufacturers. **Source:** Bureau of the Census

A 1987 profile of the paint and coatings industry based on Bureau of the Census figures shows that architectural coatings, which include both interior and exterior house paints, make up a little more than half of all paint sold in the U.S. Product coatings for the original equipment market, which includes automotive and appliance coatings, account for some 36% of U.S. paint volume. And special-purpose coatings comprise about 13% of total paint shipments. That category includes large-volume maintenance items, automotive refinishing, and coil coatings.

Shipments of architectural coatings last year increased 1.8% from 1986 to 510 million gal. However, the value of shipments rose at a faster pace—up 4.7% last year to $4.21 billion. The unit price per gal also increased 2.7% compared with 1986 to $8.24.

Product coatings shipments for the OEM sector increased 2.9% in 1987 to 360 million gal. The value of those shipments climbed 10% to $3.95 billion. Unit price per gal also increased to $10.95, up 6.9% from 1986.

The special-purpose coatings category was the only one to report an actual decline in shipments in 1987—down 2.2% from the year earlier to 133 million gal. The value of those coatings shipments, however, increased 5.3% to $2.0 billion. Unit price per gal increased significantly—up 7.6% to $15 per gal.

Just over 1000 U.S. companies are still active paint manufacturers, down from 1125 in 1983, according to consultant Rauch. Despite the number of highly publicized mergers and acquisitions in recent years, the industry remains highly competitive.

Because of the competition, product advances do not immediately translate into huge profits. Compet-

Bridge in downtown Pittsburgh is protected by three-coat paint system

Mobay photo

itors quickly catch up with advances of their own. Pricing is often a manufacturer's key to a larger share of the market and thus greater profits. And since the competition is so keen, manufacturers often temper price increases even though raw material costs increases have frequently outpaced paint price increases.

Shortages of materials have in some cases bid up the prices of paint raw materials, including ethylene-based solvents and titanium dioxide. Thus the first six months of this year have witnessed raw materials price increases greater than what paint makers have either been able or been prepared to pass along to their customers. From January to June 1988, the index for paint material prices increased 4.5% to 116.0 (1982 = 100), according to Labor Department figures. During the same period of time, the index of prepared paint prices has increased only 3.0% to 112.7 (1982 = 100).

The disparity between increases in raw materials and prepared paint prices was similar between 1986 and 1987. Raw material prices last year increased 3.2% from 1986 to an index of 107.7, and prepared paint prices increased 1.2% to an index of 108.3.

For the second year in a row, paint manufacturers continued to produce more paint in 1987 with fewer employees. According to Department of Labor statistics, the total number of production and nonproduction paint industry workers in 1987 declined 0.6% from the previous year to 63,000. The decline followed a 0.3% drop in 1986. Between 1978 and 1988, total paint industry employment declined 5700, or 8.3%, and total industry paint production fell 2.7%. Like 1978, paint production reached a peak in 1987 when total production was 1.03 billion gal.

The increasing efficiency is further shown by the number of production workers. In 1978, the paint industry employed 36,200 production workers; in 1987 it employed 30,900, a 15% decline. Employment of nonproduction employees for the same period declined marginally by 1% from 32,500 to 32,100. However, employment of nonproduction workers has declined each year since 1985 when their employment peaked at 33,600. In 1986 the number of nonproduction employees declined 2.7% from the previous year, but in 1987 it declined only 1.8%.

New technology in auto paints

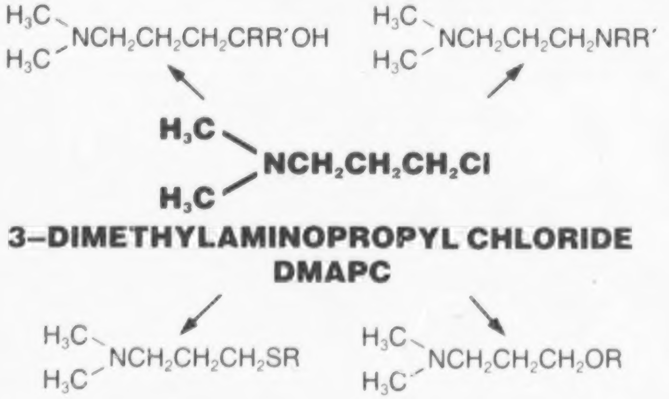
The Detroit auto makers may not be the powerhouses they were in the 1950s when just about every car parked by the roadside in the U.S. was built in the U.S. But Detroit is still pretty much the nucleus of the largest unified automotive market in the world. As such it has become the focus of an intensive fight among paint makers for a larger share of not just the U.S. but the worldwide automotive coatings business.

Each one of the Big Three automotive coatings manufacturers—BASF/Inmont, Du Pont, and PPG Industries—has spent millions of dollars over the past few years to install complex paint applications laboratories. These state-of-the-art, off-site paint production lines are set up not only to duplicate the variety of paint equipment any one car maker may have at a particular site, but also to reproduce the temperature and humidity conditions that can be met on any one car production line.

The paint companies emphasize service through these laboratories because share of market for the paint manufacturer, as well as the auto producer, means keeping up with individual consumer demand for a fashionable, flawlessly finished automobile, on the one hand, and still satisfying government environmental restrictions, on the other. Increasing government scrutiny of VOCs emitted in most wet applied paint systems is a competitive impetus in the automotive OEM paint market.

Slightly fewer than 7.1 million cars were produced in U.S. auto plants in 1987. Including imported cars, dealers sold close to 10.3 million cars last year. That means that one new car was sold for every 18 men and women over the the age of 16 last year. Autos make possible a way of life for the vast majority of U.S. residents. Many depend on their cars in some way for their livelihood. Their cars further make possible a suburban lifestyle, and,

A Versatile Building Block DMAPC



3–DIMETHYLAMINOPROPYL CHLORIDE
DMAPC

Potential Uses In Pharmaceuticals • Ag Chemicals
Curing Of Resins • Chemical Intermediates
Supplied As The Hydrochloride

Please Contact: AUSTIN

Austin Chemical Company, Inc.
9655 West Bryn Mawr Ave., Rosemont, IL 60018-5299
(312) 671-6565, Telex 280342, Telefax (312) 671-6569

CIRCLE 71 ON READER SERVICE CARD

How CAS Search Service Can Rescue You

On those days when you're facing mammoth backlogs, impossible deadlines, torturous searches for scientific information of all kinds--let CAS Search Service rescue you.

We're part of Chemical Abstracts Service, so the full range of substance and subject information on chemistry and related fields is at our fingertips. And because we use STN International we can give you worldwide information on life sciences, patents, physics, engineering, material science and more!

Now available from the CAS Search Service: Access to biopolymer sequence information! We'll search protein and nucleotide sequences on GENBANK, EMBL, PIR and on the new CASSEQ database--the only source of patent sequence data available.

Phone 800-848-6538, ask for extension 3707

...and let us rescue you!

of course, ownership of particular autos is thought to be indicative of its owners' aspirations and status in life.

Department of Commerce figures show that passenger car sales from U.S. plants declined 5.7% in 1987 from 1986, but sales are still far higher than the 5 million or so vehicles sold during the 1982 recession year. The total market that year for both domestic and imported autos was only 8 million. For the seven-month period January to July of this year, domestic auto production declined 5.9% from the comparable period last year to 4,109,307 units, according to estimates from the Motor Vehicle Manufacturers Association of the U.S. in Detroit. On an annualized basis, that is still a production volume in excess of 7 million vehicles, well ahead of 1982's recession figure. Data beginning in 1987 include the so-called "transplants," such as Honda, Nissan, and Toyota, that have auto production capacity in the U.S.

An average of 6 gal of paint necessary to coat production-line cars from phosphating to top coat means that domestic paint sales to the OEM automotive trade exceed 42 million gal. If the average cost per gallon of paint for product coatings is about the same for 1987 as for 1986, that would put OEM paint sales in excess of $425 million.

Industry analyst Rauch estimates that the combined paint sales of Du Pont, PPG, and BASF/Inmont exceeded $1.25 billion in 1986. Sales figures for the industry leaders include international automotive paint markets as well as other end-use areas for which these giants supply paint. However, each is estimated to supply about one third or slightly less of coatings demand in the automotive business, with others such as Akzo, Bee Chemical, Sherwin-Williams also active in the market.

Analysts also estimate automotive coatings shipments at about 15% of the product finishes category. That estimate can vary 10% in either direction depending on who is making the estimate as well as overall automotive sales and relative demand for other product coatings such as appliances, furniture, and food cans.

The near-term outlook for the automotive OEM coatings business "looks real good," says Kline & Co.'s Back. The manufacturing base for auto production is expanding in the U.S., he points out, with overseas-based manufacturers setting up factory production in the U.S.

Among these ventures are Toyota's joint manufacturing plant with General Motors in Fremont, Calif., operated under the name of New United Motor Manufacturing, and Honda's Marysville, Ohio, facility. In addition, Nissan, Mazda, and Mitsubishi are expected to be assembling cars in the U.S. by the end of the year. By 1990, Japanese car makers alone may have capacity to build some 1.8 million vehicles in the U.S.

With new players in the domestic market, together with the opportunities and challenges afforded by color changes and improvements in metal flake finishes and the move toward lower-VOC paints, including the introduction of both water-

Worker checks auto finish at PPG's Flint, Mich., coatings applications facility

AMP-95™ is the solution to a wide range of latex paint problems from pigment dispersion to enhancement of associative thickener performance.

How to paint yourself out of a corner

ANGUS AMP-95 functions best as a pigment dispersant. It provides for maximum dispersion of TiO_2 and other pigments. This is achieved by improving the efficiency of the anionic surfactant system. In addition, AMP-95 assures viscosity stability, improved gloss, superior scrub resistance, and better film integrity.

AMP-95 balances the surfactant system to enhance associative thickener performance which allows for complete rheological control. Associative thickner interactions can be sensitive to pH. AMP-95 provides for precise pH control.

Find out how AMP-95 can solve your paint problems. Call us.

1-800/323-6209
(In IL, 1-312/498-6700)

ANGUS®
CHEMICAL COMPANY

2211 Sanders Road
Northbrook, IL 60062
Phone: 312/498-6700
FAX: 312-498-6706

ANGUS PRODUCTS PERFORM

AC-2422

CIRCLE 9 ON READER SERVICE CARD

Kinzler: leader in top coats

borne paint technology and increasing use of powder coat technology for underhood paint applications, the next few years could prove quite interesting.

Paint makers themselves have moved to shore up their business in automotive paints. Du Pont's acquisition of Ford Motor Co.'s Mt. Clements paint plant in 1986 enlarged its domestic position, and its recently announced joint venture with ICI in Europe should reinforce its reach in the automotive paints business there.

In another recent development, C-I-L Paints, a unit of ICI's Canadian chemical operation, announced its intention to focus on automotive paints and expand into the U.S. auto paint market. Referring to successes in Canada and Europe with waterborne base-coat technology, C-I-L Paints general manager Jacob Shapiro says the "impending free trade agreement with the U.S. makes this an ideal time for us to focus all our resources on serving customers for automotive finishes in both Canada and the U.S."

Assessing the U.S. automotive OEM paint market, Kennard A. Kinzler, group vice president of automotive coatings for BASF/Inmont, says that this is the sixth year in a row in which the automotive OEM paint business has been good. More usual is a three- to four-year up-and-down cycle.

The good business environment has benefited BASF inasmuch as its coatings business takes in every segment of exterior car coats from phosphating the metal body to the final clear coat that finishes and adds shine to a new auto. A joint venture and licensing agreement with Chemetall, a Frankfurt, West Germany-based specialty chemicals company, allows BASF to manufacture and distribute the phosphate coatings needed to pretreat raw metal car bodies before the application of a primer coat. In addition, BASF benefits as a supplier of pigments for its own use as well as to other coatings formulators.

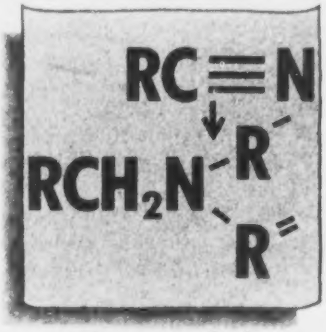
Although it supplies electrodeposition primers as well as the base color coat and clear coat for autos, Kinzler claims, "We're number one in top coats by a considerable margin. You see more of our color on top" than that of other automotive paint suppliers. However, BASF's aim is to supply the entire paint system from phosphate to top coat, thereby securing more business for itself and giving the auto assembler a single entity fully accountable for the quality of coatings supplied for the assembly line.

Ultimately Kinzler envisions a time when BASF could be responsible for managing the auto maker's paint facilities. BASF has the capability to manage such an effort, Kinzler believes, but that will only happen "if the auto makers want it."

BASF's Kinzler talks so confidently about his company's ability to manage paint applications for auto makers because of the company's new $16 million investment in its automotive applications research center in Southfield, Mich., and because of the $45 million expansion of its OEM lab and engineering research facility now under construction at the same site.

According to Lloyd E. Altamirano, the applications lab contains a 22,000-gal electrodeposition tank allowing the lab to dip prime an entire auto body. The 40,000-sq-ft facility also contains an accompanying 2200-gal small-parts dip tank, a 16,430-gal rinse tank, and a radiant convection oven. In the spray line, an auto body moves through a

Nitrile Hydrogenation.



Powerful chemistry to produce the specialty amine you need.

Our two-step process uses acrylonitrile to produce specialty nitriles which can be converted to primary, secondary or tertiary amines. Employ our expertise at the start of a commercial idea, and we'll develop the most efficient route to your new product.

The resources we can devote to your project include one of the largest and most flexible hydrogenation facilities in North America, a pilot plant and fully dedicated nitrile handling equipment. Our expert team of scientists work in some of the most modern and fully equipped laboratories in the industry.

For acrylonitrile derivatives, and for all your carbon-nitrogen-based chemical needs, call us at 800-345-3148.

©Air Products and Chemicals, Inc., 1988

More than chemicals. Chemistry.

AIR PRODUCTS

CIRCLE 3 ON READER SERVICE CARD

manual spray application booth, and then on to an automatic spray zone where paint can be applied via electrostatic turbobells and reciprocators. A developmental forced flash tunnel at the end of the line combines forced air and infrared heating. "Everyone in this lab is a chemical engineer. Most have their master's or Ph.D.," says Altamirano. And it costs BASF about $5 million annually to operate the facility, adds Kinzler.

In addition to working out paint application problems for the Detroit auto makers at the lab, European manufacturers have shipped entire car bodies to the facility for painting as well. Among them are Daimler Benz, Volvo, and Saab, Kinzler says.

BASF's engineering research facility now under construction will have close to 250,000 sq ft of lab space when it is completed, says James W. Benefiel, product development director of automotive research. About 400 people will work at the lab when it is finished, he says, up from 200 working in the lab at present.

"Helping our customer compete has become part of our job," says Kinzler. "It wasn't that way 30 years ago, but it is today." High-solids color base coats combined with high-solids clear coats have helped auto makers to produce "prettier, brighter, and cleaner colors," not possible with the older acrylic enamels and acrylic lacquers. At the same time, the high-solids formulation has helped reduce VOC problems.

The next step is to introduce a water-based color coat. In addition to even lower VOCs, the new water-based formulas allow "easier, more foolproof" application, and "even better orientation of the aluminum flakes" used in metallic finishes "for even better color." A General Motors plant soon plans to use the new water-based color coat, he says.

More durable clear coats are also a research objective, says Kinzler. BASF is researching urethane and other resin chemistry. He says that one auto maker is applying a polyisocyanate-containing clear coat formulation on the production line now and that, depending on the results on the road, it may expand the technology to its other production lines.

Du Pont also has invested heavily in automotive applications research facilities. Its Troy, Mich., lab opened in February of this year. The 36,000-sq-ft applications lab represents a $17 million investment, says Ronald F. Ellis, manager of the facility. Like BASF's, the new lab can simulate actual production-line application conditions, and includes manual as well as robotic spray zones, a convection oven, and a high-velocity flash oven containing laser-plated gold walls and ceilings for infrared efficiency for waterborne finish research.

Du Pont's interest is not just lim-

ited to coatings. Its presence in Troy represents its strength as a supplier of plastics and electronics materials as well. Says Robert P. Strazella, currently marketing services manager of automotive finishes, Du Pont's automotive products sales exceeded $2 billion in 1987. The Troy site, adjacent to General Motors' new Saturn Division headquarters, is home base for 1300 Du Pont research and sales people and world headquarters for the automotive products group. Ten years ago, only 155 people were located in Troy.

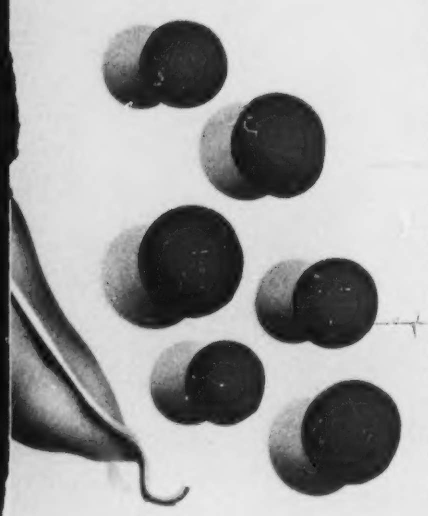
Du Pont's stance in the automotive coatings business in particular is an aggressive one. It purchased the Mt. Clements coatings operations owned by Ford in 1986 and more recently strengthened its hand in the European automotive OEM market in a venture with ICI. Technical group manager for automotive finishes Robert L. Turner expects Du Pont's OEM coatings business to grow 1 to 2% in excess of the OEM market and confesses that the only way to do that in the future will be to increase its market share at the expense of its competitors. Turner says that Du Pont's low-VOC paint technology will help the company expand in Europe, too. "They gave us the wet look, we will be able to give them systems with lower VOCs."

Like its competitors, Du Pont sees its strength as a provider of not just coatings but also service to the auto makers who use Du Pont coatings. And like its competitors, it is prepared to operate assembly-line production units for auto makers. Du Pont recently built a plant in Kansas City, Kan., where it manufactures and paints front and rear bumper fascia for delivery to a nearby General Motors assembly plant for just-in-time assembly of Pontiac's Grand Prix, says Turner.

For the future, he says, he believes basic clear coat and top coat technology will continue to be based on acrylic resins. However, he expects to see more polyester resins in combination with acrylics, though the polyester formulations need not necessarily contain polyisocyanates. The key, he says, is putting all the necessary technology together for formulations. A new proprietary technology recently developed by Du Pont and which it calls group transfer polymerization is a technique that allows the formulation of a 3 to 4% higher-solids-content, solvent-borne color coat. The resulting paint, just introduced in red, yields better color and lower VOC levels, Turner says.

Currently, he adds, Du Pont is strong in water-based color coat and solvent-based clear coat technology. The waterborne color coats enhance the appearance of the paint, notes Jack Vallance, Du Pont's automotive finishes color marketing specialist. "It allows us to return to low-solids applications," he says, thus giving finer metallic paint

The difference between our hydrazine and everyone else's.



More pure hydrazine hydrate. And fewer unwanted extras. That's what you get from ATOCHEM.

Impurities such as sodium chloride and heavy metals are virtually non-existent in our hydrazine. Which could lead to higher yields and fewer problems in your process.

Our patented production method makes the purity of our hydrazine unique. The difference: We use peroxide compounds where others use sodium hypochlorite. And since we don't start with sodium, we don't end up with related by-products.

We don't give you lots of impurities in our hydrazine, but we do give you more of what you're looking for in a supplier.

Like technical service—no one knows hydrazine better than we do. And fast delivery—we'll ship within 24 hours from one of our six warehouses throughout the U.S., in a range of packaging options from small drums to bulk shipments.

Stop paying for what you don't want. Specify ultra-pure hydrazine from ATOCHEM.

Contact Olivier Meurzec, Marketing Mgr., ATOCHEM INC., Chemical Division, P.O. Box 607, Glen Rock, NJ 07452.

For immediate help, call us Toll Free at 1-800-932-0420. In NJ: (201) 652-8575.

ATOCHEM INC.
elf aquitaine group ATO

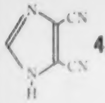
CIRCLE 14 ON READER SERVICE CARD

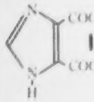
finishes than can be achieved currently with high-solids, solventborne paint systems. An advantage to paint systems that contain a waterborne solids color coat is that they allow car makers to meet all current VOC regulations while giving consumers a better-looking paint job, he says.

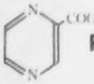
In addition, Vallance believes that waterborne color coats will allow fancy finishes unachievable with high-solids solvent paints. Not only do metal flake color finishes look better with waterborne applications, but custom names, for instance, can be painted on car decks without resorting to decals, he says.

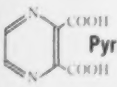
Du Pont is also putting research efforts into two-pack clear coat systems, which contain a catalyst to enhance the curing of the top coat and thus may increase the protection afforded the base color coat. But, says Turner, the two-pack systems need not necessarily contain polyisocyanates. Du Pont, he says, is looking at the systems both with and without polyisocyanates.

IMIDAZOLES
&
PYRAZINES


4,5-Dicyanoimidazole


Imidazole-4,5-dicarboxylic acid


Pyrazinemonocarboxylic acid


Pyrazine-2,3-dicarboxylic acid

and other derivatives

Nisso

Pharmaceutical dept
NIPPON SODA COMPANY LIMITED
2-2-1, OHTEMACHI CHIYODA-KU TOKYO JAPAN
TEL(03)245-6181 TELEX2222379 NISSO J
NISSO AMERICA INC.
11E 44TH ST NEW YORK N Y 10017 U S A
TEL(212)490-0350 TELEX238136 NZA UR

CIRCLE 41 ON READER SERVICE CARD

Powder coatings may also have a future in automotive exterior paint applications. Du Pont has a technology base in powder coatings, Turner says, and it remains committed to this technology through a subsidiary operating in Spain. It's possible that powder will find its niche as a chip primer applied between the electrocoat primer and the top coat where it would provide protection from pebbles kicked up along the roadside, he says. It is even possible one day that clear powder coats may provide the top coat.

Although plastics are not assembled on line before the body is painted, that may change one day. As auto makers look to more cost-effective assembly methods, a paint system that allows coating as many body parts as possible at the same time would not only reduce costs, but might also allow for better color matches, Turner says. That is one reason why paint producers including Du Pont are researching paint systems that allow oven cure of paint on auto assembly lines at 170 to 180 °F.

Temperatures along paint lines today typically reach 250 °F, but plastic parts would distort at that temperature, Turner notes. The 170- to 180-°F range could allow on-line coating of preprimed plastic parts, he says. Such a universal paint system is not a new concept, he notes, but right now the aim is to achieve a universal color coat for both the body on-line and off-line parts to achieve the best color match possible. The next goal would be to achieve an on-line universal paint ability.

Du Pont attempts to predict color demand three years ahead of a model year. In that way, the company can formulate and test the colors so it knows they will endure under long exposure to bright outdoor light.

"We check industries where color may be a factor in determining preferences by consumers for car colors," says Vallance. Men's fashions and interior design colors are two areas of inspiration, he says.

PPG also offers a full range of automotive coatings from phosphate to top coat. The company holds the key patent for electrodeposition primer coating technology utilized in two thirds of worldwide vehicle production, and licenses its competitors to sell primers based on the technology. It acquired Chemfill in 1986, giving it the ability to supply phosphating chemistry.

E. Kears Pollock, PPG director of automotive products, sets the company's automotive product business at $1 billion annually worldwide. That number includes PPG's position as a supplier of not only coatings, but also window glass and glass-fiber reinforced plastics for body panels.

PPG also has a new applications lab under construction in Troy, Mich. But lest it seem that PPG is playing a catchup game with its two major competitors, Pollock points out that PPG for years has had a Detroit area facility in Flint, Mich., capable of testing full body automotive paint applications. It also is nearing completion of a small body parts test paint application facility in the Cleveland area, he says.

The reason for the proliferation of test labs is that technology in the automotive industry is changing so fast that there is a need to test applications under real conditions, says Pollock. Auto makers want to optimize paint performance before they make the commitment to try out

Pollock: a $1 billion business annually

CIRCLE 44 ON READER SERVICE CARD→

the new techniques on their production lines.

Pollock says that auto coatings markets are strong now in Europe and North America and likely will continue strong. The Pacific area market is not so strong as it was in the past, mostly because of the relative strength of area currencies relative to the dollar. Many changes in the North American and European markets are now under way, mostly because of Asia-based manufacturers who are setting up assembly plants in both Europe and North America, Pollock says.

New developments from PPG include a powder antichip coat applied to the car body just after the electrocoat primer but before oven curing. The powder is designed to be compatible with the primer, says Pollock, and gives added antichip protection without any increase in emissions. Like its competitors, PPG has introduced new color primers that coordinate better with top coats for improved color coat appearance.

Waterborne base color coat technology is advancing, he says, as improvements in paint chemistry allow applications of waterborne formulations under a wider range of temperature and humidity conditions. The challenge in installing more waterborne systems is not only in improving the paint itself, but also the equipment. Black iron pipes deteriorate when waterborne paints flow through them. More expensive stainless steel pipe is the alternative. Where manufacturers don't want to make the investment in new pipe systems, PPG continues to develop high-flow, solvent-based solids paints that give the appearance of waterborne coatings, Pollock says.

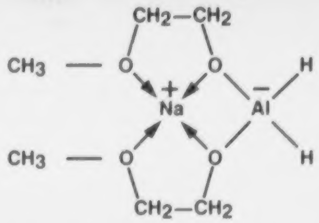
Where some manufacturers want the flexibility of using waterborne technology for lighter-colored metallic paints and solvent paints for darker colors, PPG is ready to supply them, says Pollock. "We don't think the arguments in favor of waterborne paint systems provide an open-and-shut case. We give manufacturers the option to choose."

As for clear coats, there has been a lot of interest over the years in polyisocyanate-containing clear coats because of their good appear-

← CIRCLE 44 ON READER SERVICE CARD

VITRIDE®

$NaAlH_2(OCH_2CH_2OCH_3)_2$



A Safe, Cost Effective Reducing Agent That Eliminates 3 Key Problem Areas Commonly Associated With Aluminum Alkyl Reducing Agents:

- Non Pyrophoric at ambient conditions
- Extremely soluble in a variety of solvents
- Unlimited shelf life under dry conditions

In addition, Vitride is a proven performer in large scale commercial reactions giving excellent yields, eliminating heavy precipitates and improving reactor loadings.

Hexcel's expanded Vitride manufacturing facilities assure long range supply as well as fast customer response. For samples of Vitride and a free copy of our new 36 page Vitride technical brochure, write or call:

Hexcel Corporation
215 North Centennial Street, Zeeland, MI 49464.
Phone 616-772-2193 TLX 226 375

HEXCEL chemical products

CIRCLE 34 ON READER SERVICE CARD

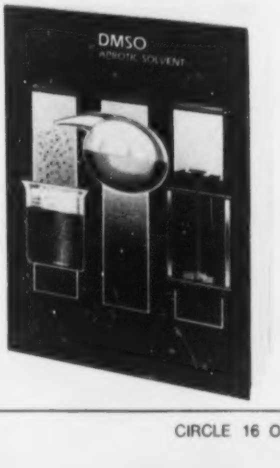
LOOKING FOR A POWERFUL SOLVENT, A COST EFFICIENT REACTION MEDIUM, OR AN EFFECTIVE REAGENT?

YOU'VE FOUND ONE.

DMSO (dimethyl sulfoxide) has a unique combination of high polarity, thermal stability, low toxicity and easy handling that make it ideal for a wide variety of industrial applications.

Including, possibly, yours. Send for our free brochure to find out more.

ATOCHEM INC.
elf aquitaine group ATO



Send me a copy of your booklet on DMSO
Name ____________
Title ____________
Company ____________
Address ____________
City ________ State ______ Zip ______
Phone ____________

ATOCHEM INC
P.O. Box 607
Glen Rock, NJ 07452
U.S.A.
Phone
1-800-932-0420
(In NJ 201-652-8575)

ATOCHEM
Direction Chimie Fine
et de Specialites
Cedex 42
92091 Paris–La Défense
FRANCE
Phone (1)49 00 80 80
Telex ATO 611922 F

CIRCLE 16 ON READER SERVICE CARD

ance and durability, says Pollock. However, because of the inhalation hazards associated with polyisocyanates, PPG has looked into alternatives. The company recently has commercialized a two-pack clear system without polyisocyanates—NCT Clearcoat—that is currently being used by Chrysler, Pollock says. He adds that he expects the technology to move to other automotive product lines in time.

"There is a lot of evidence to show that polyisocyanate-containing coatings can be used successfully," says Pollock, but the jury is still out. "Our approach is to proceed with an abundance of caution. We'll give the auto manufacturers the option."

All the major paint producers say they are providing more service these days to their customers via application lab facilities, as well as more service at customer sites. PPG engineers are responsible for paint applications at one General Motors plant. But what is important in this particular instance is not that the paint manufacturer has paint detail responsibility, but that a team of experts is free of administrative burdens and allowed to focus on the painting process.

The team approach allows a "substantial reduction of costs because of less waste," says Pollock. There are also fewer disposal problems because the volume of overspray at the plant has been reduced. Although in the end PPG may sell less paint, Pollock says that PPG "shares the savings" with General Motors through formulas in which "everyone is encouraged to be more efficient."

C-I-L Paints' Shapiro says that the entry of Japanese auto makers in the North American car assembly market affords C-I-L and its parent company, ICI, opportunities in the U.S. as well as the Canadian OEM paint market. Both C-I-L and ICI recently entered into a technical cooperation agreement with Nippon Oil & Fats Co. The Japanese paint producer supplies both Honda and Nissan in Japan.

The agreement with Nippon Oil & Fats already has helped C-I-L gain new business. C-I-L now supplies the new Honda assembly plant in Alliston, Ontario, Shapiro points out.

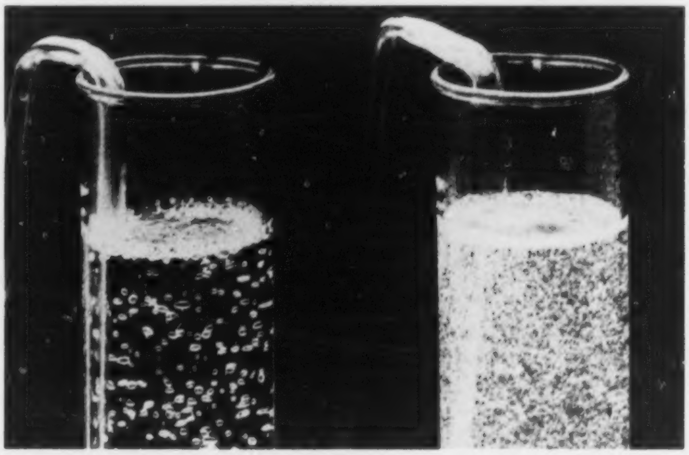
Shapiro believes that C-I-L is in a good position to compete with BASF, Du Pont, and PPG because of its recent agreement with Nippon Oil & Fats and also because it has the resources of ICI behind it. "We're competing with them in Canada," he says. Shapiro adds that he doesn't see C-I-L overtaking the Big Three in the U.S. market—"we're not large enough yet." There are "areas of opportunity," however, that should allow C-I-L to grow.

In addition to new business with the foreign companies that have auto production plants in the U.S., C-I-L's Aquabase waterborne color base coat paint technology allows it to offer a base coat/clear coat system to auto assemblers, Shapiro says. Thus it can compete directly with the three big U.S. suppliers in offering paint systems that conform to government VOC emission regulations.

Aquabase is used at a General Motors truck assembly plant in Oshawa, Ontario, and has been introduced in Sweden via ICI into Volvo's production lines, he says. "This gives us credibility. It opens the door for us in OEM in a number of areas," he adds.

Like BASF, Du Pont, and PPG, ICI is a major world plastics and automotive materials supplier. It opened a Detroit automotive service facility within the past few months, Shapiro points out. And C-I-L plans to install an automotive paint applications center in Toronto next year, he says.

As part of its efforts to beef up its production capability, C-I-L plans to spend $1.6 million (U.S. dollars; $1.00 = 1.236 Canadian dollars on Sept. 6) at its York Works manufacturing facility in Toronto. Paint production from that facility is aimed at the automotive OEM and refinish markets. C-I-L Chemical, of which C-I-L Paints is a unit, has sales of $1.05 billion. Shapiro says



Solve your mixing problems with Daxad® Dispersants.

- Keep solids suspended in liquids
- Stabilize emulsions
- Lower viscosity of slurries
- Keep dry powders free flowing
- Improve gas-liquid contact rates
- Prevent scale formation

Write for our new brochure,
"How to Handle Your Mixing Problems."

GRACE

Organic Chemicals Division, W.R. Grace & Co.
55 Hayden Avenue, Lexington, MA 02173 (617) 861-6600

CIRCLE 30 ON READER SERVICE CARD

the company does not break out paint sales separately.

Despite skepticism about the utility of two-pack polyisocyanate-containing paint systems by the major paint manufacturers, Mobay, the main industry polyisocyanate supplier, is confident that such systems can be safely applied. G. Thomas Harrick, vice president and general manager of Mobay's Coatings Division, notes the safe, wide use of polyisocyanate-containing two-pack systems in the automotive paint refinish business. He hopes to see more of a shift to their use in the OEM finishes market.

Advantages of alkyd or acrylic paint systems modified with a polyisocyanate crosslinking agent are increased resistance to gasoline spills, higher resistance to natural and artificial environmental effects from squashed bugs to acid rain, as well as a long-lasting higher and deeper gloss, says Volker Mirgel, technical marketing manager of transportation coatings.

In addition, the polyisocyanate crosslinking agent means that auto makers could operate with lower oven temperatures to cure the paint, says Harrick. Two-component polyisocyanate-containing systems also allow car makers to comply with environmental regulations, says Mirgel. More stringent environmental regulations in West Germany forced Daimler Benz to find a lower VOC paint system that would still provide a high-quality finish. The company chose a two-component system.

Mirgel explains that using a two-component top coat containing polyisocyanates allows application at relatively low viscosity. Because the polyisocyanate is added just before the spray reaches the car surface, the high-solids polymer forms on the surface of the car. In addition to lowering VOCs, the system produces a Mercedes off the paint line with a higher-gloss, smoother, more cleanable, and more durable surface. The finish also has better resistance to chemical degradation. And the system produces a more flexible film allowing a higher finish chip resistance, says Mirgel.

European car makers are more advanced than their counterparts worldwide in the use of new two-pack urethane technology, Mirgel says. Volkswagen already has a "test" paint line applying the two-component paints to 600 cars a day. The former Chrysler plants in France, now run by Peugeot, have been using the two-component systems for some time, he says. And Renault's Alpine and R-5 turbo, which both use a number of plastic components, have been using two-component urethane systems since the mid-1970s, he says.

Paint mixing/circulation room at Du Pont finishes lab in Troy, Mich.

Japanese car makers, Mirgel says, have been somewhat slower to adopt the two-component urethane systems. Nissan has started to produce its low-volume President sedan in Japan with a two-component urethane and plans to convert higher-volume production lines to the two-component clear top coat system within the next year. Toyota has not yet adopted the two-component system. Japan has no VOC emission regulations to act as an impetus. But although vehicles intended for the home market have no acid etch problems, the high number of cars subject to that problem when the cars are exported to the U.S. has made two-component urethane clear coat technology an important consideration for Japanese car makers, he says.

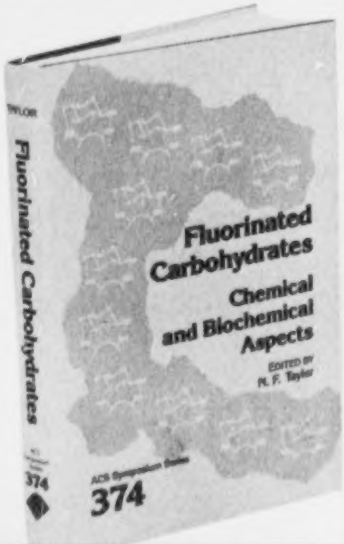
Ford's recent introduction of a two-component system at a Canadian assembly plant has been accepted by the Canadian Auto Workers Union, says Mirgel. Although Mirgel admits it's true that polyisocyanates do not have the best reputation, they can be applied safely. Mobay assisted Ford and its employees with toxicology data and helped set up an air-sampling monitoring program and a medical program for employees who might come into contact with the paint system. "We were open to gain their confidence. We didn't hide anything," says Mirgel.

There is a big difference, Harrick says, between methyl isocyanate implicated in the industrial disaster at Bhopal, India, and the polyisocyanate. Because of that disaster, "isocyanate" became a bad word, he says. But polyisocyanates used in paint have much lower vapor pressure, volatility, and toxicity than do methyl isocyanates, says Harrick. They are not based on methyl isocyanate, he stresses.

Workers must be protected when any type of paint is sprayed, and that is especially true of polyisocyanate-containing paints, Harrick says. Inhalation of spray does

Fluorinated Carbohydrates

Chemical and Biochemical Aspects



TAYLOR
Fluorinated Carbohydrates
Fluorinated Carbohydrates
Chemical and Biochemical Aspects
EDITED BY N. F. Taylor
ACS Symposium Series
374

New! First book to integrate the chemistry, biochemistry, and potential biomedical applications of fluorinated carbohydrates. Offers a versatile approach for the stereospecific introduction of fluorine into monosaccharides, disaccharides, oligosaccharides, and, in the near future, polysaccharides. Illustrates how ^{18}F and ^{19}F may replace the hydroxyl group of carbohydrates ... with minimal perturbance of molecular structure and conformation. Shows how resulting changes in biochemical reactivity, combined with the specific hydrogen-bonding capacity of the C-F bond, permit the use of deoxyfluorinated sugars in unique cellular and enzymatic processes. Discusses chemical reactivity of the carbon-fluorine bond. Emphasizes how the replacement of a hydroxyl group in carbohydrates by fluorine leads to sugar analogues of biochemical interest and potential biomedical/pharmaceutical importance.

Fluorinated Carbohydrates: Chemical and Biochemical Aspects will serve to stimulate the research of those already active in the field ... as well as to attract new researchers into this exiciting and fascinating area of carbohydrates.

N.F. Taylor, *Editor, University of Windsor*
Developed from a symposium sponsored by the Division of Carbohydrate Chemistry of the American Chemical Society

ACS Symposium Series No. 374
232 pages (1988) Clothbound
ISBN 0-8412-1492-1 LC 88-19332
US & Canada **$49.95** Export **$59.95**

Order from: **American Chemical Society**
Distribution Office Dept. 91
1155 Sixteenth St., N.W.
Washington, DC 20036
or CALL TOLL FREE

800-227-5558

and use your credit card!

Mobay's Harrick and Mercedes 190E top coated with two-component urethane

cause eye and respiratory irritation, but that is a positive sign, says Harrick. "You know right away that something is wrong." Solvents used in acrylic enamels may not cause immediate discomfort, but they may accumulate in the liver and cause a person problems in 20 years. Workers exposed to polyisocyanate-containing spray know something is wrong immediately and recover as soon as they are no longer exposed, he says.

The material cost for manufacturers to convert to paints containing polyisocyanates is not large, according to Harrick. Economies can be achieved, as was the case for Daimler Benz, which went from four-color coats to three with no loss in appearance because of the two-pack top coat.

Although Mobay is not a paint manufacturer per se, it does have an interest in raw materials for urethane coatings used in OEM automotive applications. It also supplies items such as thermoplastic resins, rubber chemicals, and pigments for the automotive business. It, too, recently opened a technical marketing center in Troy, Mich., which encompasses more than 18,000 sq ft of space, and is also linked to research labs at Mobay's Pittsburgh headquarters.

Dow Chemical is also a large supplier to the automotive business. According to Charles M. Olson, development leader in the chemicals and pigments department, the company has been instrumental in the conversion of solvents used in the industry from ethylene-based to propylene-based glycol ethers. The propylene-based solvents offer two advantages: They have lower toxicity than their ethylene-based cousins and they are more active solvents, helping manufacturers solubilize higher-solids paints.

The company, which in addition to solvents sells polymers and resins used in the automotive industry, has a Detroit area staff to coordinate the company's marketing efforts to the automotive trade. In addition, Dow is a supplier of epoxy powders used to coat under-the-hood components.

Polyester powder coats have also been used increasingly for this purpose. According to Walter F. Johnston, polyester products research engineer at Goodyear Tire & Rubber, one area in which the polyester powders have gained acceptance is as a coating for oil-filter housings. Goodyear, he says, produces and polymerizes polyester resins for powder coatings, which manufacturers such as Glidden, H. B. Fuller, O'Brien, and others convert to powder coatings.

The technology has good growth potential because it offers not only good appearance and exterior durability but some significant environmental advantages not inherent in paint. The oven-cured powders do not emit VOCs and any powder overspray can be cleaned and reused, eliminating the overspray disposal problems inherent in wet-applied paints, says Johnston.

However there are some disadvantages to powder coatings. High oven temperatures (340 to 425 °F) are now required to cure the paint, Johnston says. Those temperatures are not practical for coating most plastic parts used in autos. In addition, manufacturers must install special handling equipment for using powder coatings.

The success of different paint producers and various coatings technologies will depend in large measure on the strength of U.S. auto production. With the more competitive dollar, North American auto makers may begin to export cars in large enough numbers to have a real impact.

But should exports surge, will they come from U.S.-based auto makers or will they originate from plants set up by the "transplants?" If the "transplants" increase their exports, will they buy from the established North American suppliers or will foreign-based paint producers set up their own transplants?

Apparently U.S.-based paint producers are not leaving anything to chance. Their new paint applications facilities and the millions spent on them indicate the producers' willingness to invest big dollars in a business that may only grow 1 to 2% annually. And apparently they see it as a key to growth in sales of other materials they supply either directly or indirectly to Detroit.

Performance materials and specialty paints

Performance paint materials and specialty paints can cover a wide range of applications. Some new materials that have not been widely used, however, are now generating interest and these include organic titanates, biocides, fluoropolymers, and antirust polymers. In addition, recent advances in perfluoroalkoxy (PFA) coatings technology have paved the way for producers to open a new market in high-performance coatings for pharmaceutical and chemical process equipment.

Goldbaum: titanates used for 40 years

Organic titanates have been used in paints and coatings in some limited ways over the past 40 years, according to Richard H. Goldbaum, senior technical service chemist with Du Pont's performance chemicals group. Recent applications research has found that organic titanates are good coupling agents in paint, can provide better quality and higher yield than acid catalysts in resin manufacturing, can increase paint barrier properties aiding in corrosion resistance on metal substrates, and can help reduce viscosity in some high-solids paints.

As a catalyst in the manufacture of resins, organic titanates also can produce faster reactions and, because they are gentler catalysts than acid catalysts, they produce fewer byproducts, says Goldbaum. As surface modifiers, the titanates cost less than silanes for most applications except where adhesion to glass is a factor, he says.

Organic titanates are derived from ilmenite ore, the same source from which the premier white paint pigment titanium dioxide is obtained. Organic titanates cost between $2.00 and $6.00 per lb, says Goldbaum.

John Sices, product marketing specialist for Witco's Sonneborn Division, says the firm's SACI corrosion-prevention resin has found new life with applications in corrosion protection on industrial structures such as bridges and parking garages. For the past 20 years the SACI resin's primary use has been in the automotive market, where it has found a niche as a coating on automotive underbodies and automotive inner panels.

Hardness and abrasion resistance are not a strong point of these resins, points out Sices. However, because they have excellent metal adhesion and peeling resistance, SACI resins can provide protection where internal protection of metal structures is a problem.

Angus Chemical, Northbrook, Ill., recently has added a line of mildewcides to complement its line of in-can bactericides. In April of this year it bought Abbott Labs' Amical mildewcide business. According to John F. Alderman, product development manager, Amical is an iodine-containing organic sulfur compound.

Amical is primarily used now in adhesives, caulks, and sealants, Alderman says. Although it has been used in some prepared paint formulations, its biggest potential market is as an additive for architectural coatings. Another major use for Amical may be as an additive for stucco coatings on homes in humid climates, he says. "Safe handling and low toxicity are its major attributes," he adds.

Fluorochemicals comprise anoth-

Rao: super durable coatings

Edlon's Jenson with coating specialist and his coating equipment

er group of chemicals with potential for modifying paints. Fluorochemicals already serve several functions, says Du Pont research scientist Nandan Rao. As surfactants, they provide excellent spreading and wetting abilities. As fluoropolymers, they may be incorporated in traditional coatings to give them increased water and oil resistance as well as increased durability to ultraviolet exposure. Rustoleum, for instance, recently has introduced a wood paint for the retail market incorporating Du Pont's fluoropolymer.

Fluoropolymers also may be used in furniture finishes to provide an ultraviolet-curable "super durable" coating, says Rao. In addition, they may be used on on-line factory production equipment to provide mold-release properties where materials might otherwise stick to a fabrication mold.

New fluoropolymer-containing proprietary paint systems that make possible the coating of intricate shapes have recently come into the marketplace from at least three different companies. Edlon Products of Avondale, Pa., Ispa Plastics of Baltimore, and W. L. Gore & Associates of Elkton, Md., all offer perfluoroalkoxy coatings for use in extremely corrosive environments.

According to Bernard Jenson, applications manager for Edlon, the company has had extensive experience in the application of "Teflon loose liner" [polytetrafluoroethylene (PTFE) sheeting] to conform with interior vessel surface. Its new SC-7000 coating system allows Edlon to spray apply a 0.40-inch thick, corrosion-resistant barrier without pinholes or flaws that can give complete coverage to highly complex shapes.

The coating, he says, is very useful in reactor vessels where acids and caustics are mixed and where glass-lined vessels won't work. In addition to having a low coefficient of friction, it is serviceable at temperatures as high as 350 °F. PFA-coated distillation columns have been used to clean up acids in air by concentrating them into a liquid and have given good results.

The coating bonds best to carbon steel, a relatively inexpensive material. However, the cost of applying the coating varies from \$100 to \$200 per sq ft, depending on the complexity of the shape coated, says Jenson.

As much as 16 hours may be required to properly coat a part, he says, during which application of the proprietary dry blend powder coating is built up in successive layers and baked on in special high-temperature ovens on-site. The company has the capability to coat parts with a maximum size of 6 feet × 6 feet × 10 feet, he says.

Edlon has annual sales of \$8 million to \$10 million. Edlon's new president, Earl H. Levith, says that the market for his company's new PFA coating should considerably swell that figure. A former manager at Occidental Chemical, he believes that the market for PFA-coated vessels can run as high as \$20 million to \$30 million annually and that Edlon will be the key player in that market.

Levith says he aims to take sales up to \$25 million to \$30 million within the next five years. PFA spray-applied coatings have potential not only in high-temperature and corrosive environments but in applications where a pure product is required. Industries requiring the coating and which might help Edlon generate the level of sales Levith projects include the pharmaceutical, chemical process, and electronics industries. He hopes also that food processing will provide a market for the coatings. The company is now looking into FDA approval of the coating's use on food processing equipment. "That is a whole coating area that is virtually untapped," he says. He adds that Edlon is talking to candy, taffy, and chocolate makers, who could offset much of the cost of the coating in savings in the cost of solvents and cleaning materials used on their food-processing equipment.

Karen J. Bolin, sales manager for Ispa Plastics, a privately held company that mixes, develops, and applies specialty coatings systems, says Ispa Plastics also has a proprietary process to apply PFA coatings to processing vessels. Cost, she says, depends on the size and complexity of the part to be coated with the 0.40-inch-thick coating, but ranges between \$60 and \$125 a sq ft. However, the coating is cost-efficient for many users considering the cost of specialty metals, she points out. She estimates that 30 to 50% of vessels that are now glass-lined eventually might be coated with PFA.

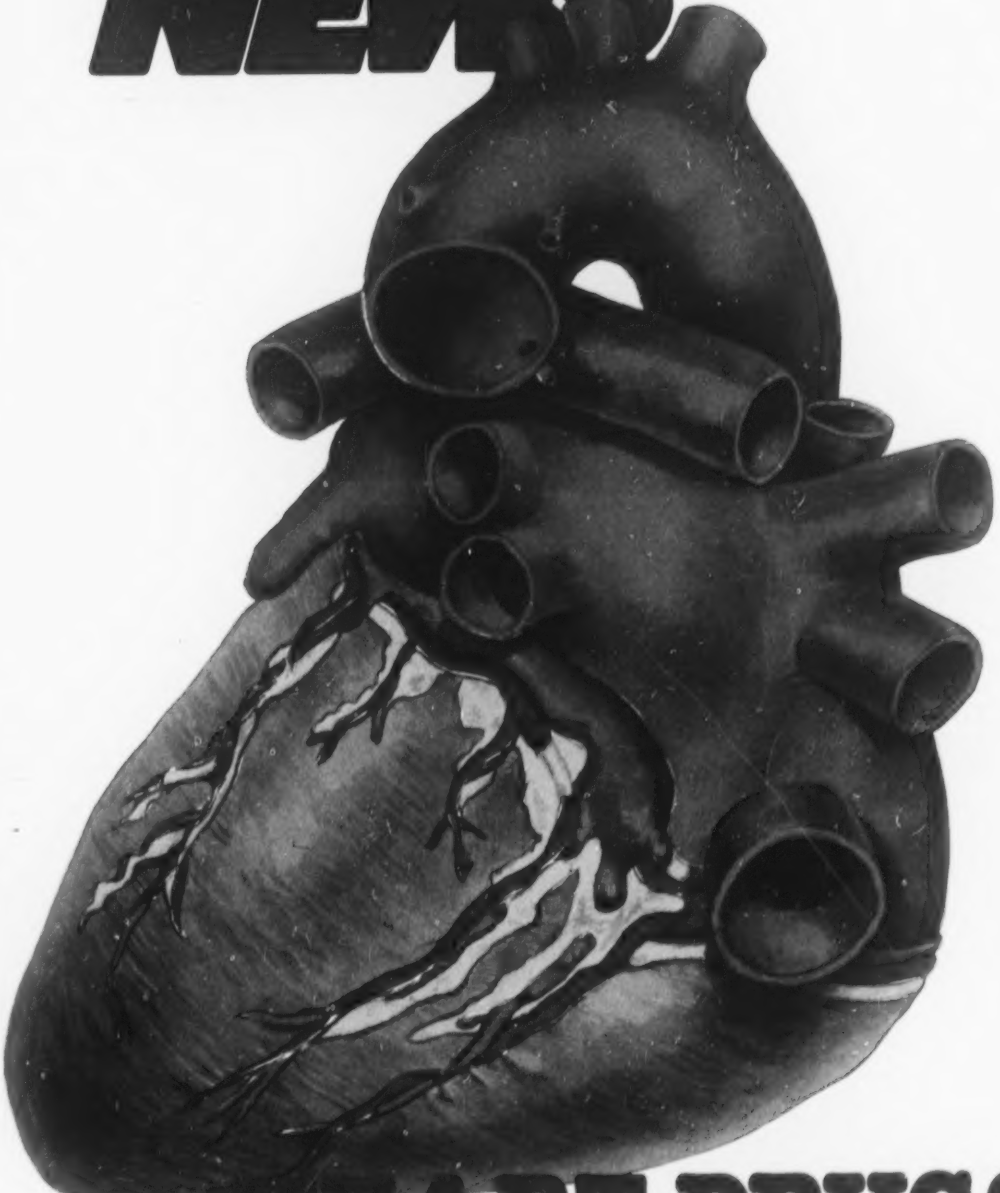
Gore is also a factor in the PFA coatings business with a product it calls Fluoroshield. A company data sheet claims that Gore's coating can be applied up to 0.60 inch thick and provides "universal chemical resistance (0 to 14 pH)" with an "operating temperature range of −190 to 260 °C." □

A1250-1
10/6/88

OCTOBER 3, 1988

CHEMICAL & ENGINEERING

NEWS



0511179C099 9 K AR6640SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

HEART DRUGS

Annual sales head toward $10 billion
Page 35

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 40
CENEAR 66 (40) 1–104
ISSN 0009-2347

OCTOBER 3, 1988

News of the Week

- **Theorists conclude that room-temperature superconductivity probably cannot be achieved in copper oxides.** **Page 6**
- **James D. Watson is appointed head of NIH's human genome research program.** **Page 7**
- **NAE president criticizes failure to establish an effective U.S. technology policy.** **Page 7**
- **EPA recommends a complete phaseout of chlorofluorocarbon and halon production.** **Page 8**
- **Chemical contamination of air, water, and food found to be worse in developing countries.** **Page 8**
- **Photos from the ACS national meeting in Los Angeles.** **Page 9**
- **ACS meeting is attended by over 12,000 conferees.** **Page 9**
- **Congressman chides chemists for their low level of activism in the political arena.** **Page 10**

Cover: John Heinly

Letters **4**

Concentrates

Business **13**
Government **18**
Science/Technology **22**

The Departments

Software/Database Update **30**
ACS Comment **74**
ACS News **76**
New Products **78**
Meetings **81**
Newscripts **104**

Business

Two plants now in startup will ease tight methanol supplies this year and into 1989, also will likely lower prices. **Page 16**

Government

Latest bill attempting to revise pesticide law was passed by the House, largely because the most controversial parts were dropped. **Page 19**

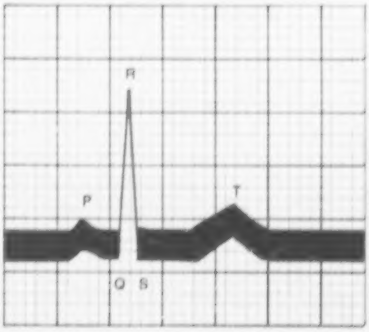
Technology

Argonne National Laboratory's coal sample program is supplying well-characterized samples of eight U.S. coal types to qualified coal researchers. **Page 29**

New type of solar cell shows promise for generating electricity and for process-scale electrolysis. **Page 32**

Books

"Effective Writing Strategies for Engineers and Scientists" and "The Basics of Technical Communicating" offer scientists instruction, encouragement, and rules of correct English. **Page 71**



Product Report

Market for cardiovascular drugs will grow 16% per year to $9.6 billion in 1992 as drug industry steps up efforts to advance therapy for disease that remains the leading cause of death in the U.S. **Page 35**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Ann M. Thayer (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Myron Foveaux, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman*: Ernest L. Eliel; *President*: Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 103)

LETTERS

Disposal of plastics

SIR: Your article on polyethylene and an impending raw material crunch (C&EN, Aug. 29, page 12) reports a growing demand for plastics. From whom? I wonder. Surely, not the consumer.

I resist the purchase of food in plastic and search the grocery store shelves for glass bottles. I ask for paper bags rather than plastic. Recently, I abandoned plastic garbage bags in favor of new "leaf" paper bags, which hold a comparable amount of garbage.

Why are we, as a nation, so eager to put a nonrenewable resource like petroleum into plastic products—especially those associated with the food industry—that have a limited product life only to go to a landfill for centuries?

Manufacturers may say that plastics are cheaper than alternatives. However, plastics are only cheaper until their disposal costs are counted.

Further, what will happen to the American economy—so wedded to plastic packaging—when the next jump in oil prices occurs? Wouldn't it make more sense to save the use of plastic for those products that need long-term durability?

Suzanne D. LaLonde
Syracuse, N.Y.

Energy conservation

SIR: The letter from Rep. Claudine Schneider (C&EN, July 11, page 2) cannot go unanswered. Because of her position, Schneider is able to influence the course of our future to a much greater extent than most individuals. The exercise of this influence needs to be tempered by a clear view of the real world.

In the first place, the business community, which understands economics very well, has for decades steadily invested in energy conservation in response to movement in energy prices. It will continue to do so as prices rise further. We need both rational conservation and the assurance of a sufficiently affordable energy supply to give people the confidence to plan for future growth. Real growth in electricity demand is averaging almost 4% a year as our economy still continues to expand. To my knowledge, no responsible people actually in the business of providing energy can subscribe to the exaggerated claims for conservation that she cites.

Second, the safety record and pollution problems of fossil-based electricity have been widely documented. There is sound justification, for environmental and safety reasons alone, to begin a program of replacing our fossil plants with nuclear plants, even with no growth in demand.

Finally, as every beginning student of nuclear technology understands, power reactors do not produce weapons-grade plutonium. It is contaminated with too much ^{240}Pu to be useful, and cannot even be separated from the spent reactor fuel without sophisticated processing facilities. It is shameful that an elected official, with the privilege of office, neglects to exercise the responsibility of being factually accurate.

B. R. McElmurry
Rancho Palos Verdes, Calif.

Doctorate in chemical research

SIR: The discussion in C&EN about contributions of non-Ph.D.s and suggestions of a doctorate in chemical research (letters by Joseph Levine, May 30, page 3; A. J. Reid, April 18, page 3; Robert M. Kuhn, March 7, page 4; and Mario Altamura, Nov. 23, 1987, page 2) remind me of the medieval religious discussion about how many angels can dance on a tip of a needle.

Actually, the issue in question is extremely simple. First, the Ph.D. title is not a prerequisite for brilliant scientific achievement. Second, a person with such achievement does not need the doctor title to enhance his or her stature.

Thomas Alva Edison's formal education was limited to three years in public school, but his scientific achievements surpass those of most Ph.D.s. I do not think that he needed the title "doctor in research" to advance his career or enhance his fame.

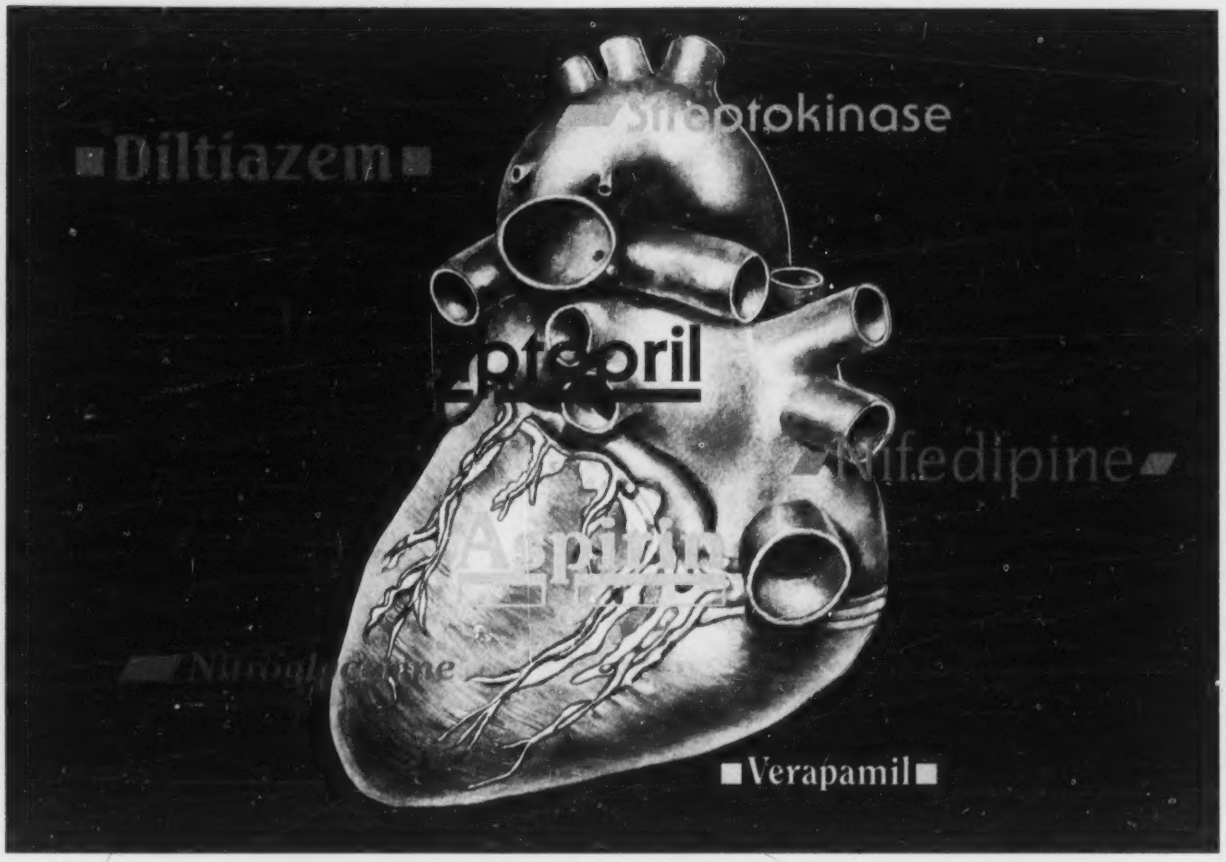
Jacob Rosin
Emeritus member
Netanya, Israel

Uses for silcones

SIR: It is with pleasure that I read Earl L. Warrick's book review of "Silicon and Silicones" (C&EN, Aug. 1, page 43).

It is not well known or publicized that both Dr. Sullivan, former director of research of Corning Glass, and Frederic Kipping had given up on silicones as giving anything practical. In fact, Kipping reports just a small amount of an oily substance as the description of the first silicones made.

In late 1938 or early 1939, Sullivan invited my father to Corning Glass to discuss silicones. At that time, Sullivan



Drug Industry Steps Up Fight Against Heart Disease

Stephen C. Stinson,
C&EN Northeast News Bureau

Despite advances in pharmacology and public awareness of risk factors, heart disease remains the leading cause of death in the U.S., accounting for 37% of the total. However, the death rate from heart disease has dropped dramatically over the past 20 years from 367 to 323 per 100,000 population. This progress has led to renewed efforts by medicinal chemists, molecular biologists, and physicians to advance therapy further.

The unparalleled potential for such advances in the near future and the sheer size of the market have caused the drug industry worldwide to devote a large share of its resources to the quest. Karl Habermas, analyst at the investment research and management firm of Sanford C. Bernstein & Co., estimates that the market for cardiovascular drugs will grow 16% per year to $9.6 billion in 1992 from $4.5 billion in 1987.

Of this 16% growth, Habermas expects approximately equal contributions to come from increased numbers of prescriptions written, price increases of established drugs, and "mix upgrade." Mix upgrade is a shift in doctors' prescribing from older to newer drugs, which are patent-protected and thus costlier.

Medical observers attribute progress against heart disease to date to reduction of risk factors for atherosclerosis, the most common cause. Risk factors include hypertension (high blood pressure), hypercholesterolemia (high concentrations of blood cholesterol), eating too much saturated fat, and smoking.

As it affects the heart, atherosclerosis is narrowing of coronary arteries, which supply heart muscle. Narrowing results from combined proliferation of smooth muscle cells through arterial inner walls, aggregation of blood platelets, and deposition of cholesterol.

When atherosclerosis reduces arterial diameters to about 20% of normal values, heart muscle may suffer chronic oxygen deprivation (ischemia). Or a blood clot may lodge at

Blaze new trails with cyclo-dextrins. Or follow the tracks of those who do.

Cyclo-dextrins can be described many ways: Cyclic clathrates…Natural ligands…Separation agents… Transport agents.

But there's just one way for your company and your products to go with cyclo-dextrins—Up!

These novel molecules can modify and stabilize highly active compounds, phase transfer, protect, shield, or catalyze.

Imagine nitroglycerin that won't explode! Or control of garlic breath. Colors and pigments more fade-proof. Fragrant fabrics.

Imagine what *you* could do with these intriguing molecules in your hands. Alert scientists are already finding new opportunities, making more creative and important contributions, extending their own knowledge as they extend cyclo-dextrins' range of applications.

Proven applications include photochemistry and electronic chemicals, pharmaceuticals, agricultural chemicals, food, and personal care. Cyclodextrins' real magic is that *nobody really knows the limits of their potential!*

Cyclo-dextrins belong in your hands today. All you have to do is call American Maize, *the only cyclodextrin producer in America.*

The choice is yours: take the lead and call us today…or follow the competitor who did.

American Maize-Products Company,
Corn Processing Division.
Call Toll-Free 1-800/348-9896.
In Indiana, call 1-800/552-9793.

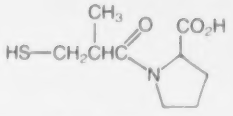
AMAIZO
American Maize-Products Company

Amaizo—Dedicated To Your Success.

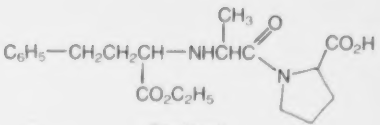
CIRCLE 91 ON READER SERVICE CARD

© 1988

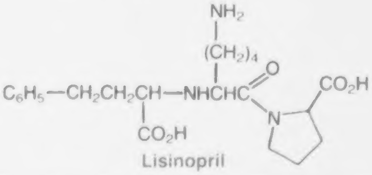
Treatment of hypertension and heart failure fuels growth for inhibitors of angiotensin converting enzyme



Captopril



Enalapril



Lisinopril

Enalapril is an inactive prodrug converted to the active agent enalaprilat by hydrolysis of the ethyl ester in the liver

the site with acute oxygen deprivation and death of some heart muscle (heart attack).

Despite increased detection and treatment of hypertension, however, incidence of atherosclerotic heart disease in treated hypertensive patients remains high. And although drugs are available to lower blood cholesterol, unpleasant side effects have limited their widespread use. Survival rates of patients with heart failure have not improved despite availability of drugs effective against its symptoms. Heart failure is a progressive loss of contractile force from effects of hypertension, ischemia, and heart attacks.

About 60 million Americans have at least mild hypertension. The incidence in blacks is almost twice that in whites.

Doctors use various criteria to diagnose hypertension, but a common one is diastolic pressure, which is pressure between heartbeats. Normal blood pressure is considered to be 120 mm Hg systolic (at the heartbeat) and 80 mm Hg diastolic.

In this scheme, diastolic pressures of 90 to 104 are arbitrarily classed as mild hypertension, 105 to 114 as moderate, and over 115 as severe. Each 5-mm Hg increase in diastolic pressure raises incidence of heart attacks 20 to 25%.

The cause of nearly 90% of hypertension is unknown, which is why it is called essential hypertension. Whatever the cause, all of the mechanisms that control blood pressure interact with one another, each causing the other to drift toward abnormal states.

Increased sympathetic nervous activity increases heart rate and pumping capacity, constricts peripheral blood vessels, and stimulates renin and epinephrine secretion. Epinephrine is a neurotransmitter that adds its effect to that of norepinephrine at sympathetic receptors. Renin catalyzes conversion of the plasma protein angiotensinogen to angiotensin I, which is converted to angiotensin II by kinases.

Angiotensin II constricts blood vessels, stimulates release of aldosterone, and degrades bradykinin. Aldosterone reduces water and sodium excretion by kidneys. Bradykinin is a naturally occurring vasodilator. Sodium triggers release of more renin.

Also, buildup of sodium in smooth muscle cells renders them more sensitive to sympathetic nervous stim-

U.S. cardiovascular drug market pushes toward $10 billion

Class	Sales, $ millions 1987	1988	1992	Annual growth
β-Blockers	$1029	$1129	$1281	4%
Diuretics	653	651	563	−3
Antihypertension[a]	577	570	675	3
Calcium antagonists	738	1121	2834	31
Vasodilators[b]	543	573	676	4
ACE inhibitors	471	774	1997	33
Cholesterol lowering[b]	202	304	1054	39
Oral inotropes[b]	67	74	228	28
Other[b]	225	234	282	5
TOTAL	$4505	$5430	$9590	16%

a Drugs used only for hypertension, principally α-blockers. b Preliminary estimates. **Source:** Sanford C. Bernstein & Co.

Organic Intermediates

- Cyanoacetic Acid
- Ethyl Cyanoacetate
- Methyl Cyanoacetate

- Triethylorthoformate
- Trimethylorthoformate
- Triethylorthoacetate
- Trimethylorthoacetate
- 1,1,3,3,-Tetramethoxypropane
- Triethylorthopropionate

- Diethyl Malonate
- Dimethyl Malonate
- Sodium Methylate

Organic Intermediates Group
10 Link Drive
Rockleigh, NJ 07647
(201) 784-0200

hüls
HÜLS AMERICA INC.
CHEMICAL DIVISION

Huls 06 01

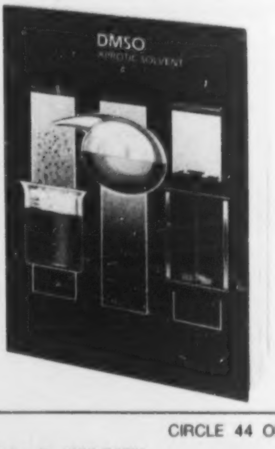
CIRCLE 4 ON READER SERVICE CARD

LOOKING FOR A POWERFUL SOLVENT, A COST EFFICIENT REACTION MEDIUM, OR AN EFFECTIVE REAGENT?

YOU'VE FOUND ONE.

DMSO (dimethyl sulfoxide) has a unique combination of high polarity, thermal stability, low toxicity and easy handling that make it ideal for a wide variety of industrial applications. Including, possibly, yours. Send for our free brochure to find out more.

ATOCHEM INC.
elf aquitaine group ATO



Send me a copy of your booklet on DMSO.

Name
Title
Company
Address
City State Zip
Phone

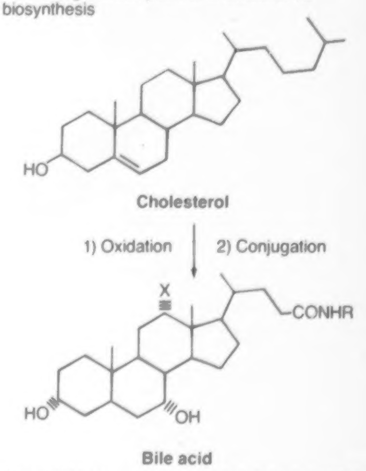
ATOCHEM INC.
P.O. Box 607
Glen Rock, NJ 07452
U.S.A.
Phone
1-800-932-0420
(In NJ 201-652-8575)

ATOCHEM
Direction Chimie Fine
et de Specialites
Cedex 42
92091 Paris—La Defense
FRANCE
Phone: (1)49.00.80.80
Telex: ATO 611922 F

CIRCLE 44 ON READER SERVICE CARD

Bile acid sequestrants stimulate cholesterol consumption

Binding and excretion of bile acids prevent their reabsorption and reuse, thus stimulating consumption of cholesterol for biosynthesis



Glycocholic acid:
R = CH_2CO_2H, X = OH

Glycochenodeoxycholic acid:
R = CH_2CO_2H, X = H

Taurocholic acid:
R = $CH_2CH_2SO_3H$, X = OH

Taurochenodeoxycholic acid:
R = CH_2CO_2H, X = H

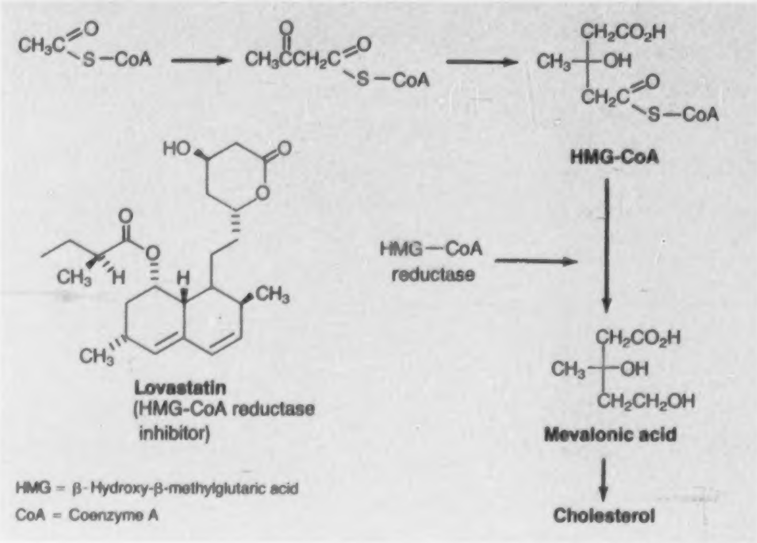
ulation and leads to accumulation of calcium. Calcium changes cross-linking of actin and myosin molecules in cells, producing contraction. Untreated hypertension causes stiffening and narrowing of peripheral blood vessels, permanently raising resistance to blood flow.

Treatment of hypertension begins with loss of excess weight and restrictions on dietary sodium. Obesity increases the load on the heart. Excessive sodium causes the body to retain water. If these measures do not lower blood pressure sufficiently, doctors go on to drug treatment.

Earliest theories of the cause of hypertension included excess fluid volume in the circulatory system. This view led to the development of a stepwise drug regimen, which begins with prescribing a diuretic, typically a thiazide. Diuretics stimulate production of urine and excretion of sodium. They can also cause excess potassium excretion, however.

Potassium is important in nerve conduction and muscle contraction, and potassium depletion (hypokalemia) is dangerous to patients

Newer cholesterol-lowering agents inhibit biosynthesis



HMG = β-Hydroxy-β-methylglutaric acid
CoA = Coenzyme A

whose hearts are subject to arrhythmias (abnormal rhythms). Doctors correct hypokalemia by prescribing a potassium supplement or an additional, potassium-sparing diuretic like amiloride, spironolactone, or triamterene.

If blood pressure remains high with diuretics, doctors go on to the next step and prescribe an additional drug, usually a β-adrenergic blocking agent ("β-blocker"). Such β-blockers as propranolol are compounds whose molecular structures resemble those of the neurotransmitters epinephrine and norepinephrine in the sympathetic nervous system.

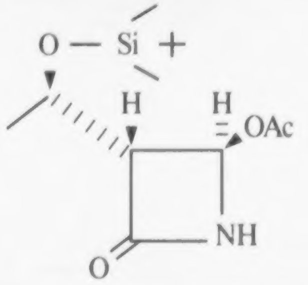
Those that block β_1-receptors in heart muscle slow heart rate and reduce contractile force. Those that block β_2-receptors in arteriolar smooth muscle dilate arterioles, thus reducing resistance in the circulatory system.

Some doctors prefer to use a β-blocker as step one and a diuretic as step two in young patients, those with angina (chest pain on exercising), and those who have had a heart attack. Black patients do not respond so well to β-blockers as do white patients, however, and β-blockers cannot be used with asthmatics. This is because blocking of β_2-receptors in bronchioles causes them to constrict.

Make Your Choice Right!
KANEKA products ensure plenty of benefits

AZETIDON-KANEKA

The Optimum Common Intermediate for PENEMS & CARBAPENEMS

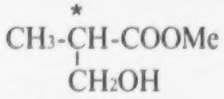


(3R,4R)-4-Acetoxy-[(R)-(tert-butyldimethylsilyloxy) ethyl]-2-azetidinone

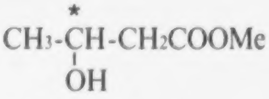
OPTICALLY ACTIVE COMPOUNDS

Various intermediates using enzymatic reactions and sophisticated syntheses are available.

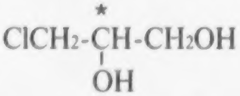
Examples


$\mathrm{CH_3\text{-}\overset{*}{C}H(CH_2OH)\text{-}COOMe}$

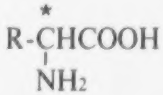
Methyl (R)&(S)-ß-hydroxyisobutyrates


$\mathrm{CH_3\text{-}\overset{*}{C}H(OH)\text{-}CH_2COOMe}$

Methyl (R)&(S)-ß-hydroxybutyrates


$\mathrm{ClCH_2\text{-}\overset{*}{C}H(OH)\text{-}CH_2OH}$

(R)-3-Chloro-1,2-propanediol


$\mathrm{R\text{-}\overset{*}{C}H(NH_2)COOH}$

D-Amino Acids

For further information please contact

Kaneka

Kanegafuchi Chemical Industry Co., Ltd.
Pharmaceuticals Division
2-4, 3-Chome, Nakanoshima, Kita-ku,
Osaka, JAPAN
Tel: 06-226-5142
Telex: KANECHEM J63582

Kaneka America Corporation
Pharmaceuticals Division
800 Third Avenue, New York,
N.Y. 10022 U.S.A.
Tel: 212-826-0002
Telex: 233701 KCIUR

Kaneka Deutschland GmbH
Pharmaceuticals Division
Abraham-Lincoln Strasse 38-42,
D-6200 Wiesbaden, F.R. GERMANY
Tel: 6121-71080
Telex: 4064191 KAD D

CIRCLE 80 ON READER SERVICE CARD

If a third drug is needed, doctors usually add the vasodilator hydralazine. Hydralazine does not affect the sympathetic nervous system but decreases availability of calcium ions in smooth muscle cells. This reduces the contractile activity of arteriolar cell walls.

If a fourth drug is needed, doctors often add an α_2-agonist like clonidine or guanethidine to the others. Stimulation of α_2-receptors in the brain inhibits release of norepinephrine to heart and arteriolar smooth muscle receptors, thus also reducing heart rate and contractile force and dilating arterioles to reduce resistance to blood flow.

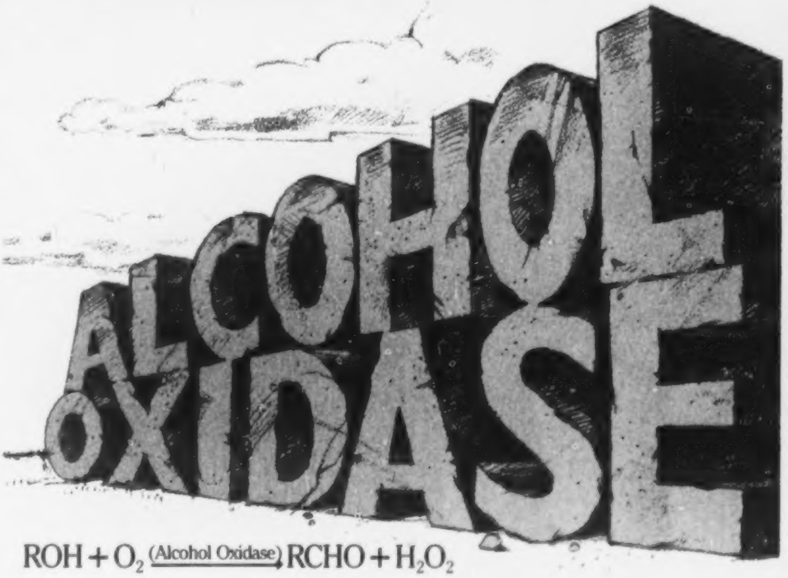
So in extreme cases, patients might take up to five drugs several times a day. Doctors worry that patients might not follow complicated medication schedules. And the cost of so many drugs might also daunt patients.

Pharmaceutical companies have responded by developing fixed combinations of drugs in a single tablet, new drugs or controlled-release forms of older drugs that are effective when taken once daily, and more potent drugs that lower blood pressure sufficiently when used alone (monotherapy). But to be useful, the fixed amounts must be identical to those that the doctor has found best for the individual patient. And it seems that every drug company can adduce clinical evidence that its newer products are effective as monotherapy.

Side effects can make treatment feel worse than hypertension, which has no symptoms until it causes heart failure, heart attack, stroke, kidney failure, or vision loss. Side effects of diuretics include impotence, and those of β-blockers include impotence and psychiatric depression. Occurrence of side effects can lead patients to stop taking medication.

Most discouraging have been studies that show that treated hypertensive patients still have a higher incidence of heart disease than the general population. One factor in this is that, although diuretics lower blood pressure, they raise serum concentrations of low-density lipoprotein (LDL) and lower those of high-density lipoprotein (HDL).

FOR SUCCESS IN PROVEN APPLICATIONS . . .
AND THOSE STILL IN YOUR IMAGINATION.



$ROH + O_2 \xrightarrow{\text{(Alcohol Oxidase)}} RCHO + H_2O_2$

You can put Alcohol Oxidase to work for you today – for a range of applications.

For instance, this affordable enzyme has been used successfully for alcohol detection where rapid and direct determination is required. Plus it's available in commercial quantities for many other uses such as alcohol removal, oxygen scavenging and chemical synthesis.

*To discover more about combining Alcohol Oxidase and the products of your imagination, contact Provesta Corporation, 15 Phillips Bldg., Bartlesville, OK 74004 USA. Or call **1-800-233-1811.** In Oklahoma and outside the USA, call (918) 661-5281. Telex: 49-2455 Phillips A Brv.*

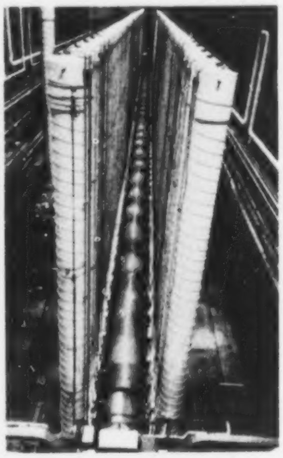
Provesta Corporation
Where innovation comes to life.®

© MCMLCXXXVIII Provesta Corporation
Provesta Corporation is a subsidiary of Phillips Petroleum Company

CIRCLE 18 ON READER SERVICE CARD

ENRICHED STABLE ISOTOPES

Produced to Your Specifications!



A gas centrifuge cascade

From KILOGRAMS To TONNES

At Cost Effective Prices!

Contact us for production availability of isotopes of the following elements:

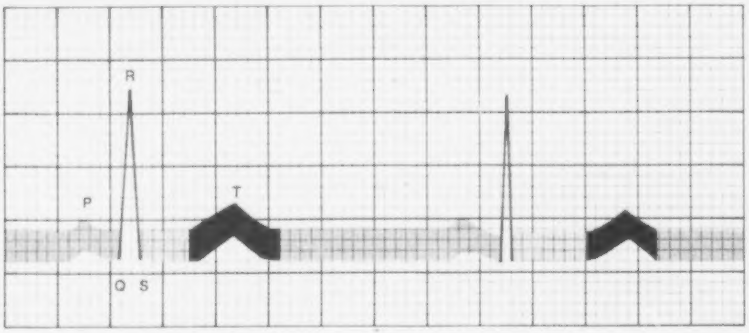
Br Cd Cl Cr Fe Ga
Ge Hg In Ir Kr Mo
Ni Os Pb Pt Re S
Sb Se Si Sn Ta Te
Tl V W Xe Zn

AlChemIE Inc.

Pine Ridge Office Park, Suite 202-B
702 Illinois Ave., Oak Ridge, TN 37830
Phone: Dr. Bruce Clark, Dir. of Mktg
(615) 482-0028

CIRCLE 90 ON READER SERVICE CARD

EKG patterns reveal electrical events in hearts



The electrocardiogram (EKG) gathers information about heart rate and rythym. It is not a mechanical record of heartbeats. Rather it records the electrical events that trigger contractions of atria, then of ventricles.

Heartbeat begins as the sinoatrial (SA) node, a clump of pacemaker tissue in the upper right atrium, depolarizes suddenly to +30 mV from −90 mV. Depolarization spreads in a domino effect throughout the atrium to the atrioventricular (AV) node at the bottom of the right atrium and is recorded as a P-wave. The AV node delays transmission of depolarization until the atria have contracted and driven blood into the ventricles.

The QRS complex starts with depolarization of the AV node. Depolarization travels down the wall between the right and left ventricles through the conductive bundle of His. The His bundle divides into right and left branches, which lead down to the bottom of the heart and up the sides of the ventricle to connect with the widely diffused, conductive Purkinje fibers in the ventricle walls. Conductive fibers in the ventricles repolarize, which is recorded as a T-wave.

Repolarization of the atria does not appear on the EKG because it is masked by the QRS complex. A U-wave sometimes appears after the T-wave and may represent repolarization of the Purkinje fibers.

LDL transports cholesterol in a way that enhances deposition on arterial walls. HDL also transports cholesterol, but high levels of HDL are associated with decreased risk for atherosclerosis.

The rationale for centering treatment around diuretics also has come into question, because excess fluid volume in the circulatory system seems important in only a few patients. Their effectiveness may come from lowering stresses of sympathetic nervous activity on blood pressure regulating systems.

Indeed, Habermas of Bernstein & Co. estimates that sales of diuretics will fall 3% per year to $563 million in 1992 from $653 million in 1987 as the number of prescriptions declines to 76.6 million from 97.7 million.

Doctors have come to focus on peripheral vascular resistance as the key element in hypertension. Increased understanding of blood pressure regulation has uncovered new targets for drugs. One target is angiotensin converting enzyme (ACE), which catalyzes conversion of angiotensin I to the vessel constrictor angiotensin II. Another is calcium, which stimulates smooth muscle contraction.

Captopril, developed by E. R. Squibb & Sons, and Merck & Co.'s enalapril and lisinopril are widely used ACE inhibitors. Such agents as nifedipine, marketed by Pfizer and Miles Laboratories, and Marion Laboratories' diltiazem are calcium channel blockers.

Doctors are encouraged both by the effectiveness of ACE inhibitors and channel blockers in lowering blood pressure and by the avoidance of psychiatric and sexual disorders as side effects. The Joint National Committee on Detection, Evaluation & Treatment of High Blood Pressure has included both classes of drugs as first-step treatment of hypertension [*Arch. Int. Med.*, **148**, 1023 (1988)].

Enalapril is approved by the Food & Drug Administration to treat hypertension and severe cases of heart failure. Captopril is approved for hypertension and both mild and severe heart failure. Lisinopril is approved for hypertension only, but Merck probably will win approval for enalapril and lisinopril for all cases of heart failure soon.

Habermas sees explosive growth potential for ACE inhibitors for both hypertension and heart failure. He estimates 33% annual growth to $2 billion in 1992 from $471 million in 1987. Though several other companies will get approval for ACE inhibitors, Habermas says that most sales will come from captopril, enalapril, and lisinopril.

The Bernstein analyst also expects growth of 31% annually for calcium blockers to $2.8 billion in 1992 compared with $738 million in 1987. This growth will come not only from hypertension but also from cases of angina, heart failure, heart attack, arrhythmias, silent ischemia, stroke, and senility. Silent ischemia is atherosclerosis that has begun to affect the heart adversely but does not yet show symptoms.

Death rates from heart disease stay high despite progress

Cause	Deaths per 100,000 population 1985	1980	1975	1970	1965
Major cardiovascular diseases	409.6	436.4	450.7	496.0	504.5
Heart disease	323.0	336.0	332.4	362.0	367.4
Rheumatic fever & heart disease	2.8	3.5	6.0	7.3	8.0
Hypertensive heart disease	9.9	10.9	5.1	7.4	28.4
Ischemic heart disease	224.8	249.7	298.3	328.1	309.4
Other disease of endocardium	4.0	3.2	2.0	3.3	6.6
Other heart disease	81.5	68.7	20.9	15.9	15.1
Hypertension	3.2	3.5	2.9	4.1	6.0
Cerebrovascular disease	64.1	75.1	90.1	101.9	103.7
Atherosclerosis	10.0	13.0	13.4	15.6	19.7
Other	9.2	8.8	11.9	12.5	7.7

Source: National Center for Health Statistics

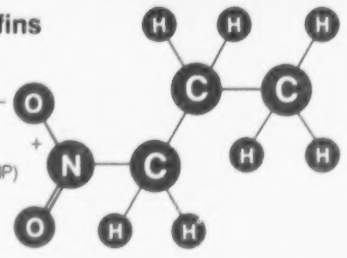
Thus, combined sales of ACE inhibitors and calcium blockers could reach $5 billion in the mid-1990s, which will be half the sales of all cardiovascular drugs.

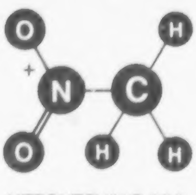
One source of calcium ions, which cause contraction of smooth muscle in arterial walls, is inflow through ion-specific channels. Drugs such as diltiazem and nifedipine block these channels, limiting inflow of calcium and keeping muscle cells in relaxed states for a longer time.

Nitroparaffin building blocks for synthesis chemists

ANGUS nitroparaffins find their way into many industries

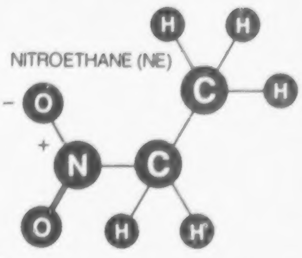
1-NITROPROPANE (1-NP)

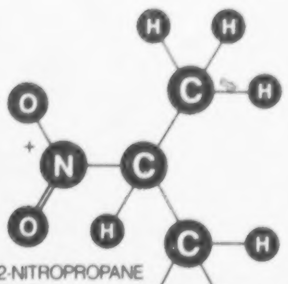




NITROMETHANE (NM)

NITROETHANE (NE)





2-NITROPROPANE (2-NP)

With the four nitroparaffins the nitro functionality can be built into many molecules through condensation and addition.

Utilizing the nitro group, you can produce nitroamines, nitroalcohols, nitronitriles, nitroolefins, or make specific useful intermediates.

The nitro group can then be used to promote further reactions at activated sites, like dehydration, halogenation or condensation reactions. The nitro function can also be converted into other functional groups including nitrile, carbonyl or amine groups.

Nitroparaffins are especially useful as reactive catalyst solvents for Friedel-Crafts alkylations and acylations, producing a complete homogenous catalyst system.

See how the four ANGUS nitroparaffins can perform when your reactions need nitro functionality such as, Nef, Mannich, Michael, Henry, Knoevenagel, and many more.

ANGUS PRODUCTS PERFORM

Send for more information from the experts in nitroparaffins.

1-800/323-6209
(In IL, 1-312/498-6700)

ANGUS®
CHEMICAL COMPANY
2211 Sanders Road
Northbrook, IL 60062
Phone: 312/498-6700
FAX: 312-498-6706

AC 2389

CIRCLE 33 ON READER SERVICE CARD

For now, FDA approval of most calcium blockers is limited to angina, although the verapamil of Knoll Pharmaceuticals and G. D. Searle & Co. is also approved for hypertension and arrhythmia. Angina is chest pain brought on by exercise, which increases heart rate and thus the heart's own need for oxygen. Narrowing of coronary arteries by atherosclerosis limits flow of oxygenated blood to the heart, starving the muscle and causing pain. Some patients also have vasospastic angina, in which coronary arteries constrict suddenly.

In addition to hypertension, high blood serum cholesterol is also a risk factor for atherosclerotic heart disease. Both the American Heart Association and National Institutes of Health recommend that cholesterol levels be reduced below 200 mg per deciliter. And the National Cholesterol Education Program Expert Panel has estimated that when concentrations are 250 to 300 mg per dL, each 1% reduction in cholesterol yields a 2% reduction in coronary heart disease rates [*Arch. Int. Med.*, **148,** 36 (1988)].

Two promising kinds of drugs to lower blood cholesterol levels are bile acid-binding resins and hydroxymethylglutarylcoenzyme A (HMG-CoA) reductase inhibitors.

Two bile acid-binding resins are Bristol Laboratories' cholestyramine and Upjohn's colestipol. Cholestyramine is a copolymer of styrene and trimethyl-*p*-vinylbenzylammonium chloride crosslinked with divinylbenzene. Colestipol is an insoluble polymer of indefinite structure made from diethylenetriamine and epichlorohydrin.

The only HMG-CoA reductase inhibitor approved by FDA to date is Merck's lovastatin. Merck also has developed simvastatin, which may be the company's entry to foreign markets, and Squibb is seeking U.S. approval for eptastatin.

Binding resins complex bile acids in the intestine for excretion in feces. Without such binding, bile acids would be reabsorbed from the intestine for reuse. Bile acids emulsify dietary fat for better digestion and are synthesized in the body from cholesterol. Enhancing excretion of bile acids shifts the equilibrium toward consumption of cholesterol.

One attraction of binding resins is that they are not absorbed in the body and so are not systemic agents. Drawbacks are that patients must consume 30 to 55 g per day, and they cause constipation in up to 20% of patients.

Physician David H. Blankenhorn led a team at the University of Southern California whose study showed that binding resins can play important roles in improving status of heart patients [*J. Am. Med. Assoc.*, **257,** 3233 (1987)]. They treated 81 men who had had coronary bypasses with a low-cholesterol diet, colestipol, and niacin, which is also a cholesterol-lowering agent. Another 81 such men got dietary treatment only.

After two years, x-rays of grafts and natural coronary arteries showed regression of atherosclerotic plaques in 16.2% of the drug group and 2.4% of the diet-only group. In the drug group, 61% had stable or improved

When it comes to quality, service, and delivery
to meet your critical production schedules,
you can count on PPG-Mazer...everytime.

MAZU DF® 200 SP (Simethicone, USP), is
available in containers tailored to your requirements.

Drug Master File #5525

SIMETHICONE,USP

PPG mazer

3938 Porett Drive, Gurnee, Illinois 60031
(312) 244-3410 TELEX (312) 244-9633

CIRCLE 16 ON READER SERVICE CARD

heart status versus 39% of the diet group. Serum cholesterol fell 26% in the drug group versus 4% in the diet group.

HMG-CoA reductase inhibitors block the enzyme that catalyzes conversion of β-hydroxy-β-methylglutarylcoenzyme A to mevalonic acid on the pathway to synthesis of cholesterol from acetylcoenzyme A. Rendered incapable of making cholesterol for themselves, liver cells respond by increasing the number of low-density lipoprotein (LDL) receptors on their surfaces.

LDL is the serum cholesterol-transporting substance that is prone to deposit cholesterol on artery walls. LDL receptors enable liver cells to absorb LDL for degradation, thus freeing cholesterol for use inside cells. This absorption also lowers serum concentrations of LDL-cholesterol. High-density lipoprotein (HDL) levels are unaffected and sometimes even raised. High HDL levels have been correlated with low incidence of heart disease and may be protective. Though the resulting reduction in serum cholesterol should be beneficial, no studies have been completed to show that HMG-CoA reductase inhibitors prevent or reverse atherosclerosis.

Habermas projects yearly sales increases of 39% for cholesterol-lowering agents to $1 billion in 1992 from $200 million in 1987. Though other oral agents are approved for cholesterol lowering, the lower incidence of side effects will garner almost 70% of prescriptions for the HMG-CoA reductase inhibitors, eptastatin, lovastatin, and possibly symvastatin, he says.

In addition to cholesterol deposition, blood platelet aggregation is a component of atherosclerosis. This may result from disruption of the balance between aggregation stimulators produced by platelets and aggregation inhibitors secreted by cells of arterial inner walls.

Newer understanding of this balance has led doctors to prescribe aspirin for angina, following a heart attack, and even as a preventive measure for middle-aged persons with no signs of heart disease. Aspirin is an inhibitor of cyclooxygenase, which catalyzes conversion of arachidonic acid released from fats to prostaglandin H_2 (PGH_2).

PGH_2 is the precursor of both thromboxane A_2 (TXA_2), which promotes aggregation and constricts arterial smooth muscle, and prostacyclin, which inhibits aggregation. Platelets are highly specialized cells that are incapable of protein synthesis. Thus, once a cell's cyclooxygenase is inhibited, it cannot make more. One aspirin tablet daily is enough to suppress TXA_2 production in the whole population of platelets as the body forms new platelets to replace those that are scavenged.

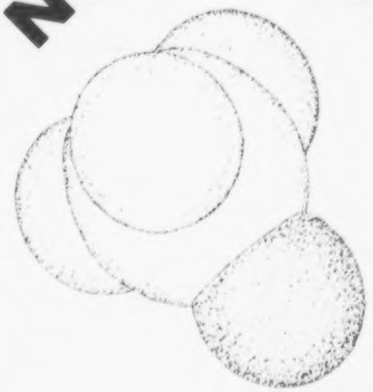
Once under way, atherosclerotic heart disease may appear as angina or heart attack. Heart attack usually

New!

MeLi 9307

Methyllithium in THF/cumene

the superior methylating reagent



MeLi 9307 offers greater safety:

Higher boiling solvent
Nonpyrophoricity
No diethyl ether

MeLi 9307 offers better yields:

Excellent adduct solubility
Clean workups
Very low halide content

Available at competitive prices and in bulk quantities.
For more information, call Lithco and talk to Bob Letchford about the benefits of lithium in your process.

LITHCO
A subsidiary of FMC Corporation

Lithium Corporation of America
449 North Cox Road
Gastonia, NC 28054
(704) 868-5300

CIRCLE 70 ON READER SERVICE CARD

results from lodging of a blood clot in a narrowed coronary artery. This acute shutting off of oxygenated blood causes death of some heart muscle. Some heart attacks come from a spasm of a coronary artery that is free of atherosclerosis. Accumulating damage from ischemia, heart attacks, and untreated hypertension produces heart failure. Heart failure is a gradually declining ability of the heart to pump sufficient blood.

Angina occurs owing to insufficiency of coronary arteries to meet oxygen demands of heart muscle. Attacks are brought on by exercise or anxiety, which increase the work of the heart and thus its oxygen demand. Symptoms include a crushing sensation in the chest, abdominal pain, and/or pain radiating from the chest to the left arm, throat and jaw, and sometimes to the right arm.

Treatment of an attack centers around easing the work of the heart

What cardiac drugs are

Atherosclerosis in the heart is occlusion of the coronary arteries, by combined proliferation of smooth muscle cells, aggregation of blood platelet cells, and deposition of cholesterol.

Atherosclerotic heart disease results in angina (chest pain on exertion), ischemia (partial deprivation of oxygenated blood), and myocardial infarction (heart attack). Accumulated damage to heart muscle by ischemia and heart attacks can lead to arrythmias (abnormal heart rhythms) and heart failure.

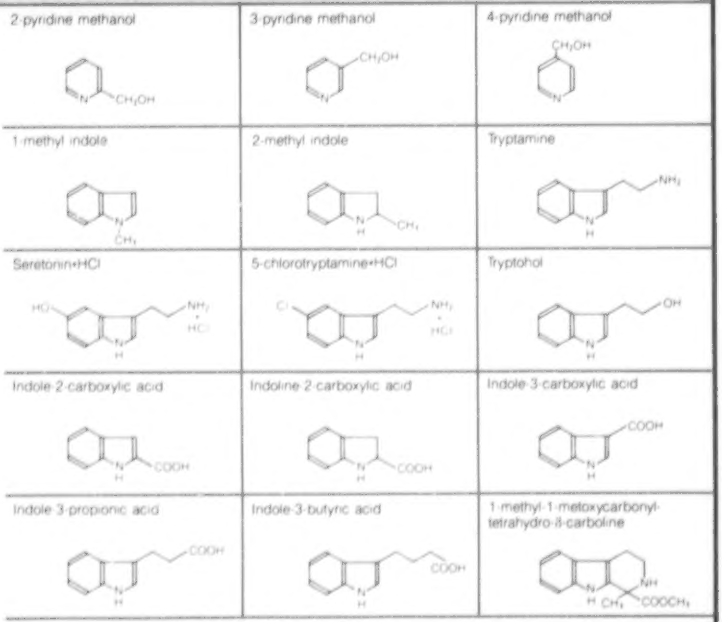
But hypertension (high blood pressure) and hypercholesterolemia (high blood cholesterol) are among conditions that accelerate atherosclerosis. And hypertension is also a cause of heart failure independent of atherosclerosis.

Some of the same drug types that control hypertension are also effective against angina and heart failure. And decisions about which antihypertensive drugs to prescribe must be weighed against their effects on arrhythmias, blood cholesterol, and heart failure.

Thus in a sense, hypertension, hypercholesterolemia, angina, heart attack, arrhythmias, and heart failure are all bound up in atherosclerotic heart disease, and the drugs used to treat these conditions are broadly cardiac drugs. Newer examples of these are α-adrenergic blockers (hypertension), β-adrenergic blockers (hypertension and angina), diuretics (hypertension and heart failure), calcium channel blockers and angiotensin-converting enzyme inhibitors (hypertension, angina, heart failure, and heart attack), vasodilators (angina and heart failure), inotropes (heart failure), and hydroxymethylglutarylcoenzyme A reductase inhibitors (cholesterol lowering).

For the Best in Pyridine, Indole, and Quinoline Derivatives, You Can Rely on Kawaken

That's because we are a world leader in the production of these and a wide range of other chemicals used in the pharmaceutical and agrochemical industries.



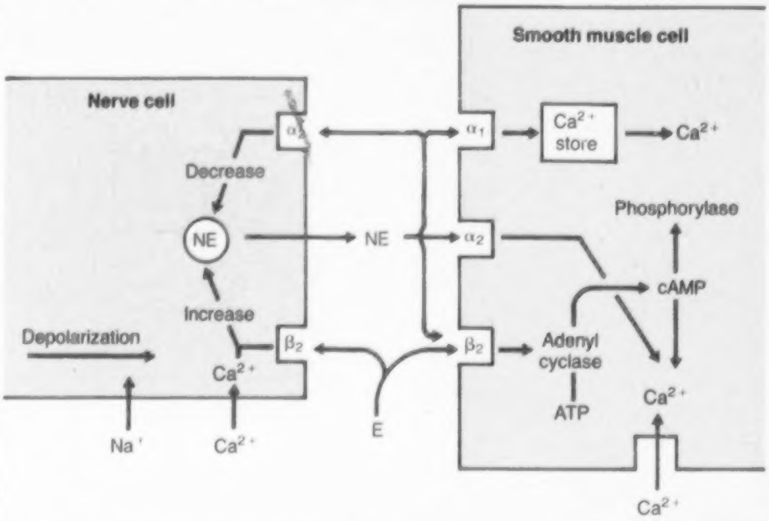
For more information write:

KAWAKEN Fine Chemicals Co., Ltd.

3-3, 2-chome, Nihonbashi Horidomecho, Chuo-ku, Tokyo 103,
Japan Telex: 252-2326 FINETK J Telephone: (03) 663-9521

CIRCLE 6 ON READER SERVICE CARD

Nerve signal triggers mechanism of muscle contraction



Wave of electrical depolarization cascades down nerve toward synapse as sodium ions rush into succeeding segments. At the synapse, depolarization draws calcium ions into the nerve cell also. Calcium causes storage vesicles to expel norepinephrine (NE), which flows into the synapse. Norepinephrine activates α_1-, α_2-, and β_2-receptors of smooth muscle cell; activation of α_2-receptors of nerve cell suppresses further norepinephrine release as a control mechanism. Epinephrine (E), secreted into bloodstream as a result of stress, also activates β_2-receptors. Activation of α_1-receptors causes release of free calcium ions from smooth muscle cell stores. Activation of α_2-receptors stimulates entry of calcium ions into smooth muscle cell. Activation of β_2-receptors triggers adenyl cyclase to convert adenosine triphosphate (ATP) to cyclic adenosine monophosphate (cAMP). cAMP also stimulates entry of calcium ions and activates phosphorylase. Calcium ions alter crosslinking of proteins actin and myosin, producing muscle contraction. Phosphorylase mobilizes glycogen to provide energy for muscle contraction.

and thus its oxygen demand. Long-term treatment of angina includes loss of excess weight, stopping smoking, exercise, and treatment of hypertension and high blood cholesterol if present.

Drugs used to treat angina are nitrate ester vasodilators, β-adrenergic blocking agents, and calcium channel blockers. One such nitrate is nitroglycerine, available as tablets placed under the tongue and ointments and impregnated adhesive patches for absorption through the skin. Nitroglycerine tablets are effective in minutes and last a half hour. Longer-acting oral nitrates include isosorbide dinitrate and pentaerythritol tetranitrate. Nitrates dilate veins, thus reducing blood pressure against which the heart must work.

β-Blockers check stimulation of the heart by the sympathetic nervous system, thus reducing heart rate. Calcium blockers are vasodilators that reduce blood pressure and inhibit spasms of coronary arteries.

About 1.5 million Americans suffer heart attacks annually, of which 750,000 are fatal. The key diagnostic tool is the electrocardiogram (EKG), which shows characteristically abnormal patterns.

Laboratory tests indicate heart muscle death by results such as increased red blood cell sedimentation rates, increased white cell counts, and raised serum levels of creatine kinase. Creatine kinase occurs as three isozymes called MM (in skeletal muscle), BB (in the brain), and MB (in the heart). Sensitive immunoassays can detect the

INTERMEDIATES FOR PHARMACEUTICALS

DEOXY-D-RIBOSE

5-FUDR

SODIUM PYRUVATE

DAD

CPA

2,6-DCA

NAGASE & CO., LTD.

TOKYO
NAGASE & CO., LTD.
Chemical 2nd Div.
5-1, Kobunacho, Nihonbashi
Chuo-ku, Tokyo, Japan
Tel. 03-665-3370 (Mr. Miura)
Telex, J26480

NEW YORK
NAGASE America Corp.
500 5th Ave. New York
N.Y. 10110, U.S.A.
Tel. 212-354-3140 (Mr. Nishimura)

DÜSSELDORF
NAGASE (Europa) GmbH
Am Wehrhahn 41
4000 Düsseldolf 1
F.R. Germany
Telex, 8588686 (Mr. Yamashita)

CIRCLE 85 ON READER SERVICE CARD

THE UNITING FORCE

No matter how tough your mixing problems are, Thompson-Hayward has the surfactants and emulsifiers to handle them.

Manufactured to the highest quality standards in a variety of formulations, T-DET® surfactants and T-MULZ® emulsifiers solve your mixing problems. They simplify production and optimize performance of products ranging from detergents to pesticides.

But maybe you have a mixing problem that is unique. For that situation, we offer custom formulations developed in our laboratories to meet your specific needs.

And for your defoamer needs, we can supply you with T-H silicone or non-silicone antifoams.

All our products are available for prompt delivery from our more than 30 nationwide distribution centers.

Whatever your requirements, contact our Specialty Chemical Divison at 913-621-7751. Because we're more than one of the nation's largest distributors.

We're the primary source for your specialty chemical needs.

SPECIALTY CHEMICAL DIVISION

T-H THOMPSON-HAYWARD CHEMICAL COMPANY

A member of the Harrisons & Crosfield Group
P.O. Box 2383, Kansas City, Kansas 66110

YOUR PRIMARY SOURCE.

T-DET and T-MULZ are reg. TM's of Thompson-Hayward Chemical Company

330-184

CIRCLE 28 ON READER SERVICE CARD

MB isozyme and avoid false positive tests.

In the past, doctors could treat heart attacks only by decreasing the heart muscle's oxygen needs to limit the amount of muscle death and by waiting for the blood clot in the coronary artery to dissolve naturally. Intravenous morphine relieves pain and anxiety; lidocaine corrects arrhythmias; atropine increases an abnormally slow heartbeat; β-blockers lower heart rate to reduce muscle work; and nitroglycerine, isosorbide dinitrate, or sodium nitroprusside lowers high blood pressure.

Plasmin helps dissolve the blood clot naturally by catalyzing chain breaking in the blood clotting protein fibrin. Plasmin is generated from the circulating precursor plasminogen by kinases.

In recent years, drug companies have developed such kinases as urokinase, streptokinase, and tissue plasminogen activator (t-PA) to treat heart attack. Until now, it was thought that these agents were effective only when delivered by a catheter directly into the coronary artery.

A catheter is a tube inserted by opening a distant artery and moving it through the arterial system via the aorta to the coronary artery. This arduous procedure requires specialized facilities available in only one out of five U.S. hospitals and must be done within six hours of onset of symptoms.

Most recent studies show that slow intravenous infusion of these kinases is also effective. And mortality rates drop even further when doctors give aspirin also to prevent reformation of blood clots.

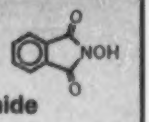
Hoechst-Roussel Pharmaceuticals and KabiVitrum market streptokinase in the U.S., produced from cultures of hemolytic streptococci. Though streptokinase opens 60% of coronary arteries and has shown lower mortality rates, this bacterial protein causes allergic reactions in 10 to 15% of patients.

Beecham Laboratories has developed a complex of plasminogen with streptokinase whose active site is anisoylated. This agent has the advantage that it can be given as a single injection. Slow hydrolysis of

ORGANIC INTERMEDIATES FROM SWITZERLAND

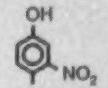
for
- pharmaceuticals
- agrochemicals
- dyestuffs
- flavors
- fragrances
- photochemicals

N-Hydroxyphthalimide

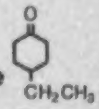


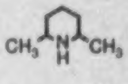
NEW

4-Amino-3-nitrophenol



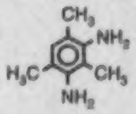
4-Ethylcyclohexanone



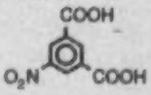


2,6-Dimethylpiperidine, cis

2,4-Diamino-1,3,5-trimethylbenzene (2,4-Diaminomesitylene)



5-Nitroisophthalic acid and derivatives



Custom synthesis against secrecy agreement

Our traditional processes:
- nitration
- catalytic hydrogenation and other reactions

US-Agents:
HENLEY CHEMICALS, INC.
50, Chestnut Ridge Road
Montvale, NJ 07645
Phone (201) 307-0422
FAX (201) 307-0424

— 75 years —
SSF DOTTIKON

CH-5605 Dottikon/Switzerland
Phone: 057 26 11 55
Telex: 827 923 ssf ch
Telefax: 057 24 21 20

CIRCLE 26 ON READER SERVICE CARD

The Custom
Chemical Manufacturer
With More Than
Customary Service

*Your Mark
of Excellence
For Custom
Chemicals*

Rütgers

Ruetgers-Nease is one of the fastest growing custom manufacturers of pharmaceuticals, agricultural, and specialty chemicals and intermediates. That's because our customers get an extra measure of value — out-of-the-ordinary service such as special handling and speedy turnaround.

We offer state-of-the-art quality control and reliable scale-up by a team of professionals. Our plants are fully equipped with 1,000 and 2,000 gallon glass and stainless steel reactors; centrifuges, stills and driers. And we're proven process innovators, capable of producing hundreds of tons with complex processes. Our special skills are in the area of multi-step organic synthesis, including a full range of chemical reactions.

We've built our reputation and our success on doing the job right the first time . . . on going the extra mile for our customers . . . and, working in complete confidentiality and regulatory compliance. Call or write today to arrange a meeting in our office or yours.

Ruetgers-Nease
Chemical
Company, Inc.
201 Struble Road
State College, Pennsylvania 16801
(814) 238-2424
FAX No. 814-238-1567

CIRCLE 21 ON READER SERVICE CARD

the anisoyl group frees the active site of streptokinase for activation of the associated plasminogen. Beecham plans to apply for U.S. approval soon and has signed an agreement with Upjohn to market the drug in a combined effort.

Abbott Laboratories markets urokinase, made from tissue cultures of kidney cells, approved for treatment of heart attack by catheterization. The company is seeking additional approval for intravenous use of urokinase.

The only t-PA now approved in this country is that of Genentech, produced from cultures of Chinese hamster ovary cells and approved for intravenous use. The company used a plasmid to insert the human t-PA gene.

Genetics Institute is cooperating with Burroughs Wellcome Co. in clinical trials of t-PA. The two have formed WelGen Manufacturing Co. as a joint venture with a plant in Greenwich, R.I., to make t-PA and other agents derived from biotechnology.

Integrated Genetics has developed a modified t-PA in which the asparagine at position 120 is changed to glutamine. The change prevents glycosylation at that site and increases the half-life to 30 minutes from two to five minutes. For now, the company is testing only in Japan, with the firm Toyoba.

As a biotechnological alternative to aspirin to prevent reocclusion of coronary arteries, Centocor has produced monoclonal antibodies against the blood platelet glycoprotein IIb/IIIa receptor. Centocor also expects the product to be effective against reocclusion following coronary angioplasty.

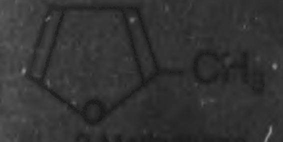
Coronary angioplasty is a procedure to treat angina by inserting a balloon through a catheter into the coronary artery. On positioning the balloon at the narrowed site, doctors inflate the balloon, which compresses the atherosclerotic plaque and widens the artery.

Controversy has erupted over the relative costs of clot-dissolving kinases. The amount of streptokinase for a course of treatment costs about $200, whereas that of Genentech's t-PA is $2200. Abbott spokesmen say that the cost of urokinase also

AVAILABLE FROM
QO CHEMICALS

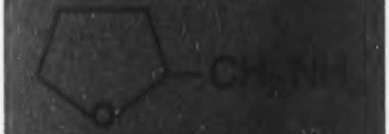
COMMERCIAL PRODUCTS

2-Furoic Acid



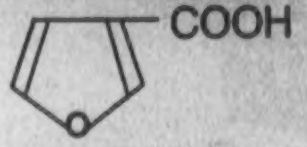
2-Methylfuran

2-Furfurylamine

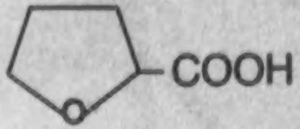


2-Tetrahydrofurfurylamine

DEVELOPMENTAL PRODUCTS



3-Furoic Acid



2-Tetrahydrofuroic Acid

For more information,
write or call:

QO Chemicals, Inc.
Subsidiary of Great Lakes Chemical Corp.
2801 Kent Avenue, P.O. Box 2500
West Lafayette, IN 47906
Phone: 317/497-6232

QO
CHEMICALS

QO-1123

CIRCLE 96 ON READER SERVICE CARD

would be about $2200. Beecham has not set a U.S. price for its anisoylated plasminogen-streptokinase activator complex (APSAC), but it probably will be much higher than that for streptokinase.

The U.S. Prospective Payment Assessment Commission, which makes recommendations about what procedures Medicare and Medicaid should pay for, has decided that there are no clinical differences between streptokinase and t-PA, and that the higher cost of t-PA is not justified. This picture could change with the publication of results of studies of whether or not t-PA lowers mortality rates.

Genentech has offered to reimburse hospitals for the cost of its t-PA used to treat indigent patients. Such patients must earn less than $25,000 per year and not be covered by private or government health insurance.

Dissolving of a clot in a coronary artery leads to sudden reperfusion of heart muscle with oxygenated blood. Sudden reperfusion can lead to tissue damage. Biochemistry professor Joe M. McCord of the University of South Alabama and his collaborators have suggested that this damage is caused by oxygen-derived free radicals. The enzyme superoxide dismutase (SOD) prevents formation of such radicals and thus may play a role in treatment of heart attack.

In this view, oxygen starvation in heart muscle leads to metabolism of adenosine triphosphate to hypoxanthine. Ordinarily, hypoxanthine would be converted to xanthine harmlessly by xanthine dehydrogenase. But increased amounts of calcium entering heart muscle cells triggers change of the dehydrogenase to an oxidase.

Xanthine oxidase uses oxygen to produce xanthine and superoxide radical anion. Superoxide liberates iron from the protein ferritin, and the iron catalyzes formation of tissue-damaging hydroxyl radicals from superoxide.

Additionally, McCord has suggested that superoxide activates a blood factor that attracts cells called neutrophils to the site as part of an inflammation reaction. Neutrophils also produce superoxide. Thus, re-

Custom Manufacturing

partnership

ROHNER

Rohner chemistry – Efficiency by creativity

ROHNER

CIRCLE 20 ON READER SERVICE CARD

- **Vital for chemists, scientists, managers, and executives**
- **Meet the challenges of environmental concerns**
- **Learn to deal with federal regulations**

Toxicology for Chemists

Wednesday–Friday, November 16–18, 1988
Belleview Biltmore Resort & Spa
Belleair–Clearwater, Florida

A Short Course produced by the
American Chemical Society

Concern with toxic substances, so widespread now that it pervades almost all scientific activities, has created a large demand for toxicologists. Specialists who can handle problems in the production and distribution of chemicals, in the environment, and in foods, drugs, cosmetics, and wastes, and especially those who can effectively cope with the challenges of federal regulations will benefit from the intensive training and education this course provides. Learn the general principles of toxicology and how to apply a practical approach to making decisions in the field. Ideal for those who seek expertise in toxicology to advance or alter their careers.

Course contents cover:

Regulatory Affairs
Quantitation in Toxicology
Carcinogenesis
Acute and Chronic Toxicity Testing
Inhalation Toxicology
Mutagenesis
Teratogenic and Reproductive Effects
Liver Toxicology
Neurotoxicology
Metabolism and Toxicokinetics
Predictive Toxicology
Toxicokinetics

Course Instructors

Dr. Frederick J. DiCarlo, Consultant, U.S. Environmental Protection Agency heads the faculty who teach this course. The lecturers are leaders in their fields, recognized nationally for their expertise and teaching experience.

For detailed information on this course, write, send coupon, or CALL COLLECT (202) 872-4508, ext. 801.

American Chemical Society
Education Division
1155 Sixteenth St., N.W.
Washington, DC 20036

☐ Please send me full details on the ACS Short Course "Toxicology for Chemists," to be held November 16-18, 1988 in Belleair-Clearwater, Florida.

Name ____________________
Title ____________________
Organization ____________________
Address ____________________
____
City, State, Zip ____________________
Business Phone ____________________

perfusion would lead to a burst of superoxide radicals within heart tissue, which would attract neutrophils to produce even more superoxide.

Therapy against reperfusion damage might include an anti-inflammatory drug to limit the process in the long term as well as SOD to limit the process throughout.

Firms involved in developing SOD include Bio-Technology General, Chiron, and Sterling Drug. Bio-Technology General is collaborating with Bristol-Myers to test SOD after angioplasty at Johns Hopkins University. Chiron's testing is limited to reperfusion damage to kidneys before transplant. Sterling has inherited the SOD program of Eastman Pharmaceuticals following acquisition of Sterling by Eastman Kodak.

Patients whose hearts are damaged by heart attack, ischemia, or untreated hypertension often develop heart failure. Heart failure is a progressive process in which the heart no longer pumps enough blood for the body's needs. About 2 million Americans suffer from the condition.

With atherosclerotic disease or hypertension, the process usually begins with enlargement of the left ventricle. The left ventricle is the chamber that receives oxygenated blood from the contracting left atrium and itself contracts to pump blood to the body through the aorta.

The left ventricle wall becomes increasingly stretched in the relaxed state and cannot contract with sufficient force to pump the normal fraction of blood it contains. This results in high filling pressures on the next delivery of blood from the atrium.

Receptors in the body detect the reduced output from the heart and respond by raising blood pressure. Increased blood pressure increases the work of the heart and causes further enlargement and reduced pumping capacity.

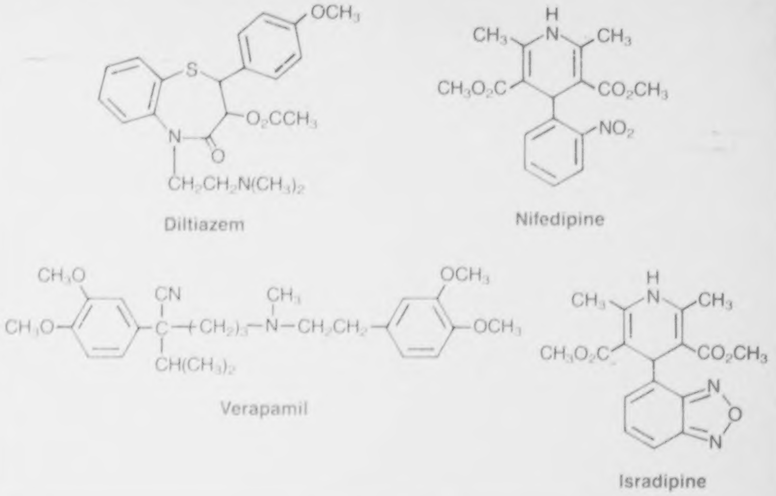
High filling pressures back up into the pulmonary system, causing high blood pressures there. High pulmonary vessel pressures force water through vessel walls to fill air sacs in the lungs. Blood flowing past fluid-filled sacs is not aerated, and this further reduces the quality of heart output.

Treatment of heart failure includes rest. The minor tranquilizer diazepam helps achieve this during the day and the hypnotic flurazepam at bedtime.

Associated high blood pressure is treated as hypertension with salt restriction, diuretics, and vasodilators. Just after diagnosis, doctors often use the potent, fast-acting, potassium-sparing diuretic furosemide. Digitalis suppresses arrhythmias that may develop in the weakened muscle, lowers heart rate, and increases contractile force.

But until recently, despite drug treatment that relieved symptoms and increased ability to exercise without fatigue and breathing difficulties, mortality rates were 50% within five years of diagnosis. Then, long-term studies by the Veterans Administration [*New England J. Med.*, **314,** 1547 (1986)] showed an average 28% improvement in survival rates using hydralazine and isosorbide nitrate. Hydralazine is an arterial dilator and isosorbide dinitrate a venous dilator. In the Cooperative North Scandinavian Enalapril Survival Study, a consortium of doctors showed similar improvements of survival rates with the ACE inhibitor enalapril [*New England J. Med.*, **316,** 1429 (1987)]. These results offer hope that medicinal chemists can discover new agents that actually improve survival rates in heart failure. □

Sales of calcium channel blockers to hit $2.8 billion in '92



Diltiazem

Nifedipine

Verapamil

Isradipine

PFANSTIEHL LABORATORIES, INC
Products
PFANSTIEHL LABORATORIES, INC
Profile
TO MEET SPECIAL NEEDS
PFANSTIEHL LABORATORIES, INC
PRODUCT CATALOG

Everything you need to evaluate a company who wants to be your carbohydrate supplier . . . and more!

Yours Free! Find out what other companies are discovering: that as a quality chemical company serving industry, health care and the life sciences . . . Pfanstiehl Laboratories can do it all.

With a breadth of line that includes pharmaceutical intermediates, bulk finished pharmaceuticals, diagnostic chemicals, anti-viral building blocks and more. With a developmental laboratory and pilot plant that features the most advanced equipment and technology on the market. With a highly skilled staff eager to work with you.

Read all about it. Send for this free literature package today. Put Pfanstiehl to work for you.

PFANSTIEHL LABORATORIES, INC.

The source for carbohydrate chemistry

1219 Glen Rock Avenue
Waukegan, IL 60085-0439
Tel: 1-312/623-0370
Fax: 312/623-9173
Telex: 25-3672 PFANLAB

49-G

CIRCLE 14 ON READER SERVICE CAR

70

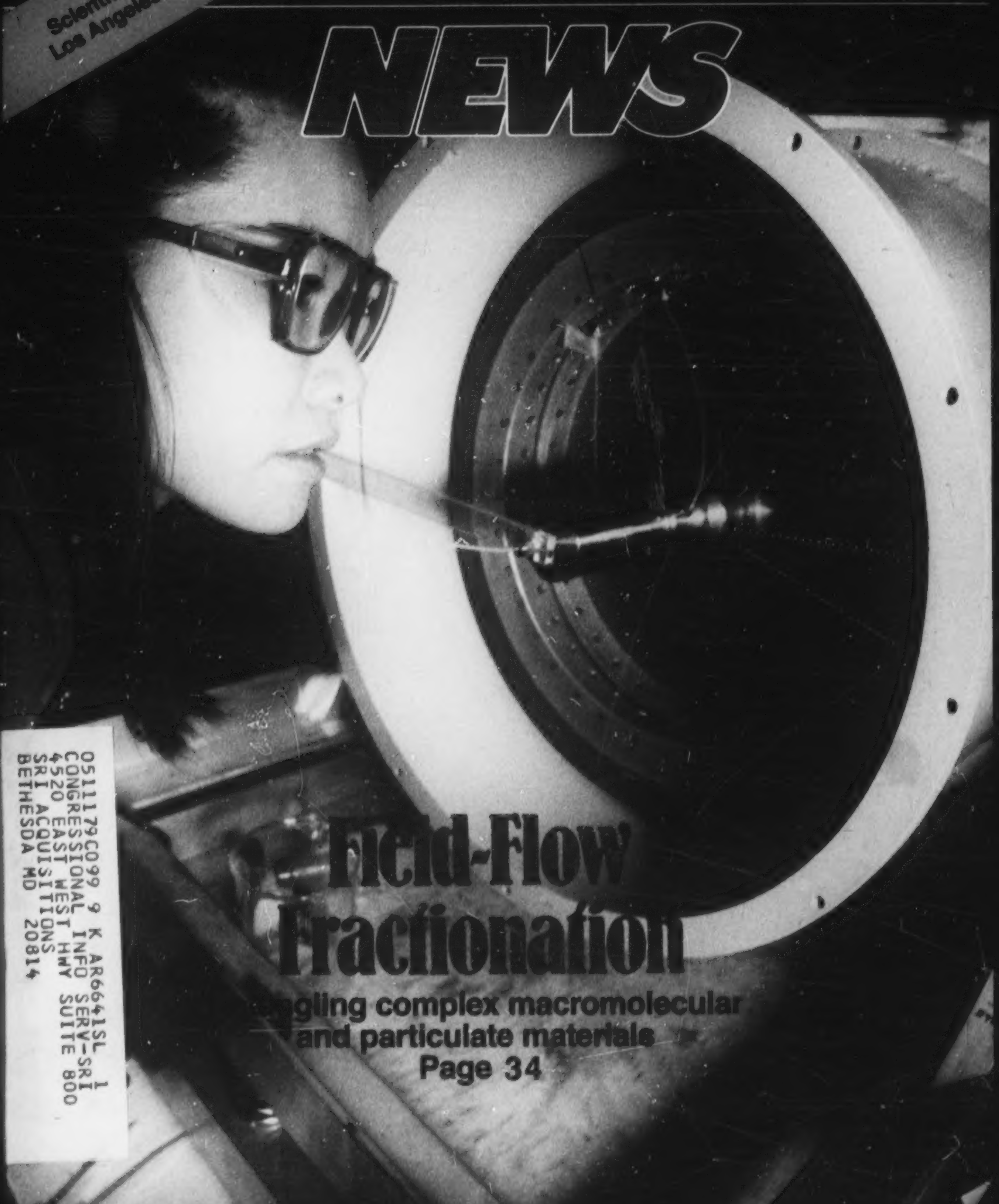
BEST AVAILABLE COPY

A1259-1
10/13/88

OCTOBER 10, 1988

CHEMICAL & ENGINEERING NEWS

Scientific news from the Los Angeles ACS meeting



Field-Flow Fractionation

ngling complex macromolecular and particulate materials
Page 34

0511179C099 9 K AR6641SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 66, Number 41
CENEAR 66 (41) 1–64
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

OCTOBER 10, 1988

News of the Week

- **The space shuttle *Discovery* was a big success—revamped components passed their first flight tests, and scientific experiments went off smoothly.** Page 4
- **Congress just got under the wire in passing the remainder of its 1989 appropriation bills.** Page 5
- **McGraw-Hill's *Chemical Week* magazine has been sold to a U.K.-U.S. investor team.** Page 5
- **General Motors has launched a nationwide science education program for primary and secondary schools based on solar-powered car.** Page 5
- **Congressional study of current methods for detecting pesticide residues offers suggestions for improvements.** Page 6

Cover: Centrifuge used for sedimentation field-flow fractionation studies at University of Utah is examined by researcher Kim Ratanathanawongs. Channel in which FFF takes place, which extends around the circumference of the centrifuge basket, is located between the silver-colored rings. Photo by Alexis Kelner

Letters 2

Concentrates
Business 7
Government 17
Science/Technology 21

The Departments
Meeting Briefs 32
Newscripts 64

Business

SCI medalist Vincent Gregory recalls his years at Rohm & Haas, voices concerns about the chemical industry; the strong Canadian uranium industry is getting stronger; the U.S. uranium industry continues in doldrums; plastics composites industry will record its fourth straight year of growth in 1988. **Page 9**

Government

Upcoming election won't bring any big changes in makeup of the Congressional committees that oversee science issues. **Page 18**

Science

From the Los Angeles meeting: chemists closing in on synthesis of taxol, a scarce natural product with potent anticancer activity; first dinitrogen complex of an f-element synthesized; novel technique for studying solid-state reactivity developed. **Page 22**

Education

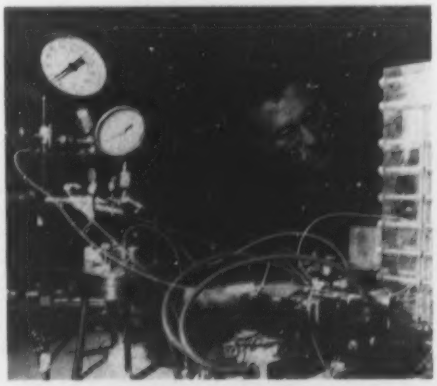
New study says knowledge of science among precollege students is generally lower than levels found in initial 1969 survey; from the Los Angeles meeting: ACS program takes science to elementary school students. **Page 25**

Technology

The Los Angeles meeting continued: new hydroformylation catalysts have as much as 100 times the activity of previous ones; chemical sensors find growing use in microanalysis; technical and economic progress made in direct coal liquefaction. **Page 27**

ACS News

Scenes from Los Angeles meeting, which offered participants a variety of activities, captured on film by C&EN's roving photographer. **Page 46**



Special Report

Field-flow fractionation provides a versatile array of methods for separating the components of complex macromolecular and particulate materials, while also characterizing separated components. Page 34

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin

Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski

Staff Editor: Ernest L. Carpenter

Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer

Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer

Service Departments Editor: Dolores Miner

Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Ann M. Thayer (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)

Graphics and Production: Leroy Corcoran (Manager), Alan Kahan (Art Director), Barbara Fryer (Production/Art Director), Linda Mattingly (Staff Artist), Diane Kelly (Costing). **Business Manager:** Arthur Poulos

Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve, and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210. (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 63)

LETTERS

Fluoridation of water

SIR: I congratulate you and your staff, particularly Bette Hileman, on the special report "Fluoridation of Water" (C&EN, Aug. 1, page 26). The article is, to me, a manifestation of the ultimate essence of what the American Chemical Society can be at its very best. The article addresses within the specifics of fluoridation a number of fundamental issues that confront and confound scientists and the public alike in endeavors to resolve societal issues involving science and technology. It is a case study that displays fundamental issues that I and many others endeavor to address in general terms. Some of these issues are:

- The distinction between a goal (to improve dental health) and a technological mechanism (fluoridation of water) to pursue that goal.
- The potential for misadventure (unbalanced research programs, selective use of data, biased analyses of data, sequestering of data, restriction of publication, and misdirection of research funds in general) of designing research programs to support a specific political position on a technological option as compared to designing research programs to further the attainment of a goal.
- The potential conflict of roles of an individual as a scientist (an expert) and as an advocate of a technological option related to the field of expertise.
- The role of value judgments in the selection and implementation of a technological option (mechanism) to address a societal issue.

The report has not been written as a case study, but the elements of a case study are there.

Anna J. Harrison
Mount Holyoke College

SIR: In the special report on fluoridation of water, the author says, "For 43 years, there seems to have been no middle ground between the two points of view [for and against fluoridation]. She also quotes a Natural Resources Defense Council attorney, "Neither side has given the other one rational moment."

This is the equal-time approach favored by television commentators to attract viewers to programs where science is confronted by opponents, such as programs on biotechnology or on creationism. Equal time for what? Unfortunately, antifluoridationists, like other detractors of science, are unrestrained by adherence to veracity, so that science loses ground. The allegation that sponsors of fluoridation have not given their opponents one rational moment is quite false.

I, and many others, have tried for many years to rebut—rationally—factual misrepresentation by antifluoridationists. For example, in 1980, they made a statement in an official pamphlet sent to all Oakland, Calif., area voters, that the National Academy of Sciences (NAS) stated that "fluoride is not an essential nutrient, therefore deficiency is impossible." At my instigation, this statement was declared untrue by the president of NAS. Actually, NAS, in "Recommended Daily Allowances" (1980) said, "Fluorine can be considered an essential element for the growing organism on the basis of its proven beneficial effects on dental health. . . . The Food and Nutrition Board recommends fluoridation of public water supplies where it is needed because of low natural fluoride levels."

The deplorable special report contains many questionable statements against fluoridation that need a lengthy rebuttal.

Thomas H. Jukes
University of California, Berkeley

SIR: I was disappointed and dismayed by your recent article and editorial on the fluoridation of water. This biased and misleading review in my professional journal is very disturbing.

Although it can be argued that there are two sides to any scientific question, it is totally inappropriate to emphasize an essentially discredited position, especially when the great majority of these antifluoride data has been questioned by peer review. The length of the article (17 pages) and the complete distortion in the quality, quantity, and sophistication of the scientific data do great disservice to the American Chemical Society and cast grave doubt on your scientific judgment.

There is no conspiracy to withhold the truth about fluoridation, because there is no scientific case to support the antifluoridation position—a case that is based largely on philosophical and emotional issues.

This article, not peer-reviewed, should not be permitted to suggest in any manner that it reflects the position of ACS. Action must be taken immediately to rectify the appearance that this is an ACS official position.

The dental associations should be commended for their support of fluoridation, despite the political and economic pressures that they have experienced. Despite the economic impact that fluoride has had on the dental profes-

Canadian uranium industry growing stronger

U.S. uranium producers may not much like the idea of competing with Canadian uranium producers in the U.S. and world markets, but they can't help but admire the strength with which their Canadian counterparts can play the game.

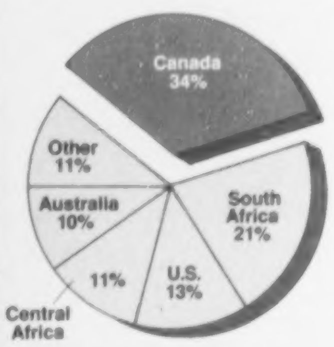
The Canadian uranium industry is the world's leading uranium producer and exporter. It produces about $820 million (U.S. dollars; $1.00 U.S. = $1.22 Canadian) worth of material per year and exports about 85% of it.

To the chagrin of their competitors, Canadian uranium producers have been doing this for years. Now several recent developments figure to make them even more formidable competitors. One is a new policy on nonresident ownership in the Canadian uranium mining sector.

Another is the merger of Saskatchewan-owned Saskatchewan Mining Development Corp. (SMDC) with Eldorado Nuclear Ltd., owned by the federal government, to form a new, world-class integrated uranium mining and processing company. The Canadian government owns 38.5% and the Saskatchewan government owns 61.5% of the new company called Cameco—Canadian Mining & Energy Corp. The eventual goal is to privatize the company.

Another development that is certain to help Canadian uranium producers is the Canada-U.S. free trade agreement. The agreement, signed on Jan. 2, 1988, has been passed by the U.S. Congress, but is being held up by opposition parties in the Canadian Senate. The federal election Prime Minister Brian Mulroney has called for next month likely will determine the fate of the agreement in Canada. The election is slated for Nov. 21.

Canada leads western world in output of uranium



1987 U_3O_8 production = 13.0 million lb

Source: Canadian Mining & Energy Corp

The free trade pact is very important to the future of the Canadian uranium industry, says Richard M. Williams. Williams, a uranium adviser in the Uranium & Nuclear Energy Branch of Energy, Mines & Resources Canada, notes that the U.S. is Canada's largest uranium customer, accounting for more than one third of total exports. Canadian uranium producers supplied more than 40% of U.S. domestic requirements last year. Canada, in fact, is the largest single source of uranium for U.S. utilities.

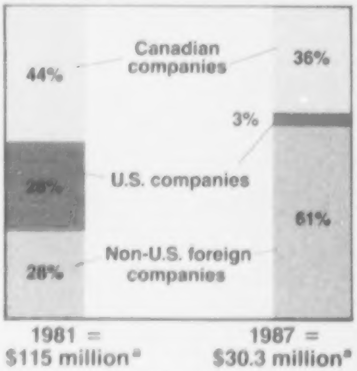
The free trade agreement benefits both Canada and the U.S., Williams told a recent Uranium Seminar, sponsored by the U.S. Council for Energy Awareness (USCEA) in Tucson. He was careful not to say that it benefits the "U.S. uranium industry." For Canada, the agreement ensures that Canadian producers won't be hit by restrictions prohibiting foreign uranium from being enriched in the U.S. Canadian producers will remain exempt, too, from any import restrictions that may be imposed in the U.S. by new legislation.

For the U.S., says Williams, the pact means that U.S. utilities will have access to Canadian uranium, even when Canada may be in short supply and in a mood to limit exports. Under the agreement, Canada also has agreed to exempt the U.S. from the Canadian Uranium Upgrading Policy.

This means that U.S. refiners and converters will be able to compete for the job of converting—that is, upgrading—Canadian uranium exported to the U.S., either to be consumed or transformed for shipment to third countries. Normally, Canadian uranium has to be upgraded in Canada before it leaves the country. As a result of the agreement, says Williams, U.S. companies could compete for the refining and conversion business associated with about 70% of Canada's uranium exports.

Non-U.S. foreign firms are big in Canadian uranium

Canadian uranium exploration expenditures



[a] U.S. dollars, $1.00 = $1.22 Canadian.
Source: Uranium & Nuclear Energy Branch, Energy, Mines & Resources Canada

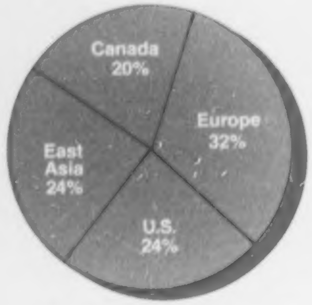
Representatives of U.S. uranium companies in the audience were less than impressed. Their industry has been declared "nonviable" by the U.S. Secretary of Energy for three successive years. Most of them fought the free trade pact's uranium provisions every step of the way. And most of them still want some kind of restrictions imposed on uranium imports.

Williams, however, questions such proposals. He notes that the U.S. uranium industry had been protected by a Department of Energy restriction on enriching foreign uranium that was imposed in 1967. This 100% embargo lasted 10 years and was not completely phased out until 1984.

Williams says that this restriction "totally disrupted the international uranium market and contributed to . . . significant overcapacity in the U.S." Much of that overcapacity, he adds, has since been proven to be uneconomic.

Meanwhile, competitors will have to contend with Cameco, the integrated company with $1.2 billion (U.S.) in assets. In the privatization of the company, the provincial and federal governments' shareholdings will be reduced 30% within two

Most of Canada's uranium is exported



Uranium shipments[a] = 10,020 metric tons

[a] Average annual scheduled deliveries (as of mid-1987) for the five-year period 1987–91.
Source: Uranium & Nuclear Energy Branch, Energy, Mines & Resources Canada

years, 60% in four years, and will disappear in seven years. No individual Canadian will be able to own more than 25% of the voting rights and no individual non-Canadian will be able to own more than 5%. Total non-Canadian shareholdings will be restricted to no more than 20% of the votes cast at shareholder meetings.

This year, says company vice chairman R. E. (Roy) Lloyd, Cameco will supply about 16% of the western world's uranium from its three operating mines (Key Lake, Rabbit Lake, and Cluff Lake). A fourth mine —at Cigar Lake—now is in what Lloyd calls "the predevelopment stage."

According to Lloyd, the Cigar Lake property, discovered in 1981, is the largest high-grade uranium deposit in the world. "The potential of this deposit cannot be exaggerated," he says.

Lloyd figures that Cameco will control 40% of Canada's known, economic uranium resources. It also will operate Canada's only uranium processing plants at Blind River and Port Hope, Ontario.

Meanwhile, Canada's new foreign ownership policy, it is hoped, will lure more foreign investment dollars into the Canadian uranium industry. When it was announced by the Minister of State for Forestry & Mines late last year, its primary objective was to make sure that Canadians owned 51% of an individual uranium property when production begins.

However, says EMR's Williams, the government would allow lower levels of Canadian ownership "if Canadian control can be clearly demonstrated." Only when Canadian partners cannot be found would the government consider exemptions to these rules. And these exemptions would require cabinet approval.

Despite these limitations, Williams says the new foreign ownership policy gives both foreign and domestic investors considerably more flexibility than they had under the old policy. The first foreign taker under the new policy is Korea Electric Power Corp., which bought a 2% nonvoting interest in (now Cameco's) Cigar Lake uranium project.

Foreign, but not U.S., companies are heavily involved in Canadian uranium exploration. Last year, says Williams, non-U.S. foreign companies accounted for more than 60% of the money spent to look for uranium in Canada. Although the dollar figures are less [only $30.3 million (U.S.) total last year], that non-U.S. foreign share is up from only 28% in 1981.

U.S. companies' interest in exploring for Canadian uranium has waned. Their share of exploration spending has dropped from 28% in 1981 to 3% last year. Most of that money came from U.S. oil companies. However, Williams believes that, if the free trade agreement is given the green light, it, along with Canada's new foreign ownership policy, could rekindle the interest of U.S. companies in Canadian uranium.

That remains to be seen. What is certain is that, at the end of last year, Canada estimated its uranium resources stood at a hefty 1.23 billion lb. This represents what can be recovered at about $112 per lb. Almost half of those resources are much less costly to mine.

A mushrooming spot market drove average Canadian export prices for uranium down to $23 per lb as U_3O_8 last year. Few producers in other countries are able to survive at that price level.

Earl Anderson

U.S. uranium industry still in trouble

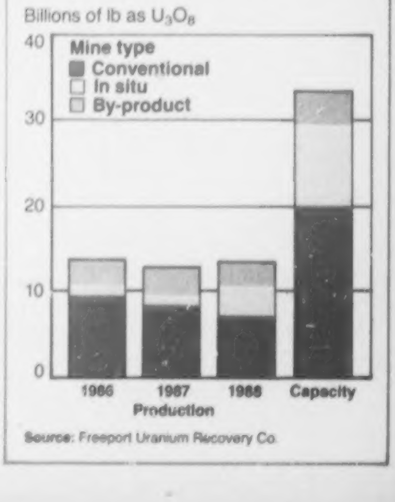
The Secretary of Energy has declared the U.S. uranium mining and milling industry to be "nonviable" for three successive years, 1984–86. He no doubt will declare that it was nonviable again in 1987.

As utilities have turned away from nuclear power, uranium prices have nosedived. Low demand and low prices have taken their toll. Over the past five years or so, the mining and milling industry, or at least some firms in it, has been fighting to get help from the government, through the courts and through legislation. So far, without luck.

The industry's hardship helped trigger more than a little cynicism at the recent Uranium Seminar sponsored by the U.S. Council for Energy Awareness in Tucson, Ariz. Ludwig W. Koch, a principal in Uranium Consulting Services (Atlanta), notes that the U.S. uranium industry has shrunk to one fourth the size that it was 10 years ago and that it has become "a ward of all three branches of our federal government."

The federal courts, he says, are being asked to impose an embargo on foreign uranium to raise prices and sales (the Supreme Court recently threw out that request). Congress, adds Koch, is being asked to enact a guaranteed buying program

Uranium output is small shadow of capacity



Source: Freeport Uranium Recovery Co.

Plastics composites use continues to grow

The U.S. plastics composites industry continues to do well, according to figures from the Composites Institute of the Society of the Plastics Industry. With 1988 being the fourth year in a row of growth for the industry, shipments this year are projected to approach 2.7 billion lb, 6.3% more than in 1987, based on performance in the first two quarters of 1988.

"The continued growth in composites shipments during the first half of this year is all the more significant coming off such a strong 1987," says Carl. C. Rue, chairman of the Composites Institute and vice president for corporate planning and development with CertainTeed Corp. In 1987, shipments reached a record 2.54 billion lb, an unexpected 11% increase over 1986. Although 1987 was a record year, shipments are already expected to total 1.39 billion lb in the first six months of this year.

Polymer-based composite materials, including reinforced thermoset and thermoplastic resin composites, reinforcements, fillers, and polymer concrete, have applications in a wide variety of industries; the transportation industry is the largest share of the market at 25% (670 million lb), and the marine and construction industries follow closely, each at 19% (about 500 million lb).

The marine industry at 21% and the aircraft, aerospace, and military sector at 12% are leading the demand growth for composites in 1988. All nine market sectors are showing some degree of growth, although the levels vary widely between a low of 0.6% for the construction industry to a high of 21% for the marine industry.

Transportation as the largest consumer of composites at 25% (670 million lb) also has a low level of growth at 2%. Future growth in the use of composites in this area is expected, especially in the auto industry, which is the single largest segment of the transportation market. Rue points out that the Big Three U.S. auto makers—Chrysler, Ford, and General Motors—have recently established a joint research consortium for the study of the applications of polymer-based composites in the auto industry. It is hoped that this study will lead to an increased use of composites in the auto industry.

The marine industry has grown most steadily in its share of the market over the past three years. Composites shipments to the marine industry are expected to increase 3% from 1987, thus finishing 1988 at a level of 19% of the market. Other areas such as appliances and business (151 million lb), consumer products (173 million lb), and electrical and electronics (224 million lb) continue to be strong with shipments growing about the same rate as the overall composites market.

The use of light, high-strength, reinforced materials is expected to continue in designs in the aircraft, aerospace, and military sector. If advanced aircraft systems are brought into production, many of which consist of more than 80% composite materials, shipments to this industry are expected to rise for many years from the present level of 41 million lb. Since 1988 is an election year, prospects for this market hinge on the election results and defense policy in the near future.

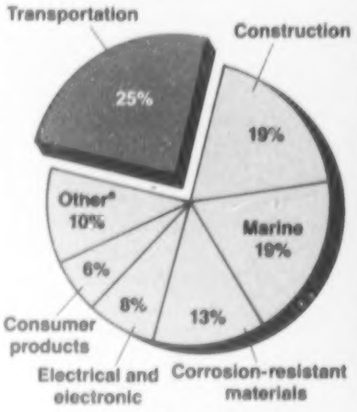
The growth in the use of corrosion-resistant composites has been tied closely to production in other industrial areas. Capacity or near-capacity production in the chemicals and petrochemicals areas has accelerated the demand for replacement parts, pipes, and tanks and has caused the market to grow from 291 million lb in 1986 to a projected 345 million lb in 1988.

Production of some composites, such as those using glass fibers, may be limited by the production capabilities of the necessary intermediates. Demand for glass fibers is currently being met through debottlenecking efforts and near-capacity production, according to Rue. Chemical intermediates also may be in short supply. However, Rue says that supply problems might soon be easing.

Forecasts for quantities of composites shipments in the last two quarters of 1988 show little change from the first two quarters, with 1988 expected to finish at record levels.

Ann Thayer

Transportation takes big share of composites



Total estimated 1988 shipments = 2.70 billion lb

a Includes appliances, aircraft, aerospace, and military.
Source: Composites Institute, Society of the Plastics Industry

Marine uses of composites show fastest growth

Millions of lb	1988[a]	1987	1986	Change 1987–88
Aerospace and military	40.8	36.4	37.0	12.1%
Appliances and business	151.3	140.5	137.0	7.7
Construction	508.8	506.0	456.0	0.6
Consumer products	173.0	166.5	149.0	3.9
Corrosion-resistant equipment	345.0	329.0	291.0	4.9
Electrical and electronic	224.0	214.0	201.0	4.5
Marine	500.0	412.6	340.0	21.2
Transportation	670.0	656.0	585.0	2.1
Other	82.6	75.3	83.0	9.7
TOTAL	2695.5	2536.3	2279.0	6.3%

a Based on six-month estimates and projections for the remainder of the year. Source: Composites Institute, Society of the Plastics Industry

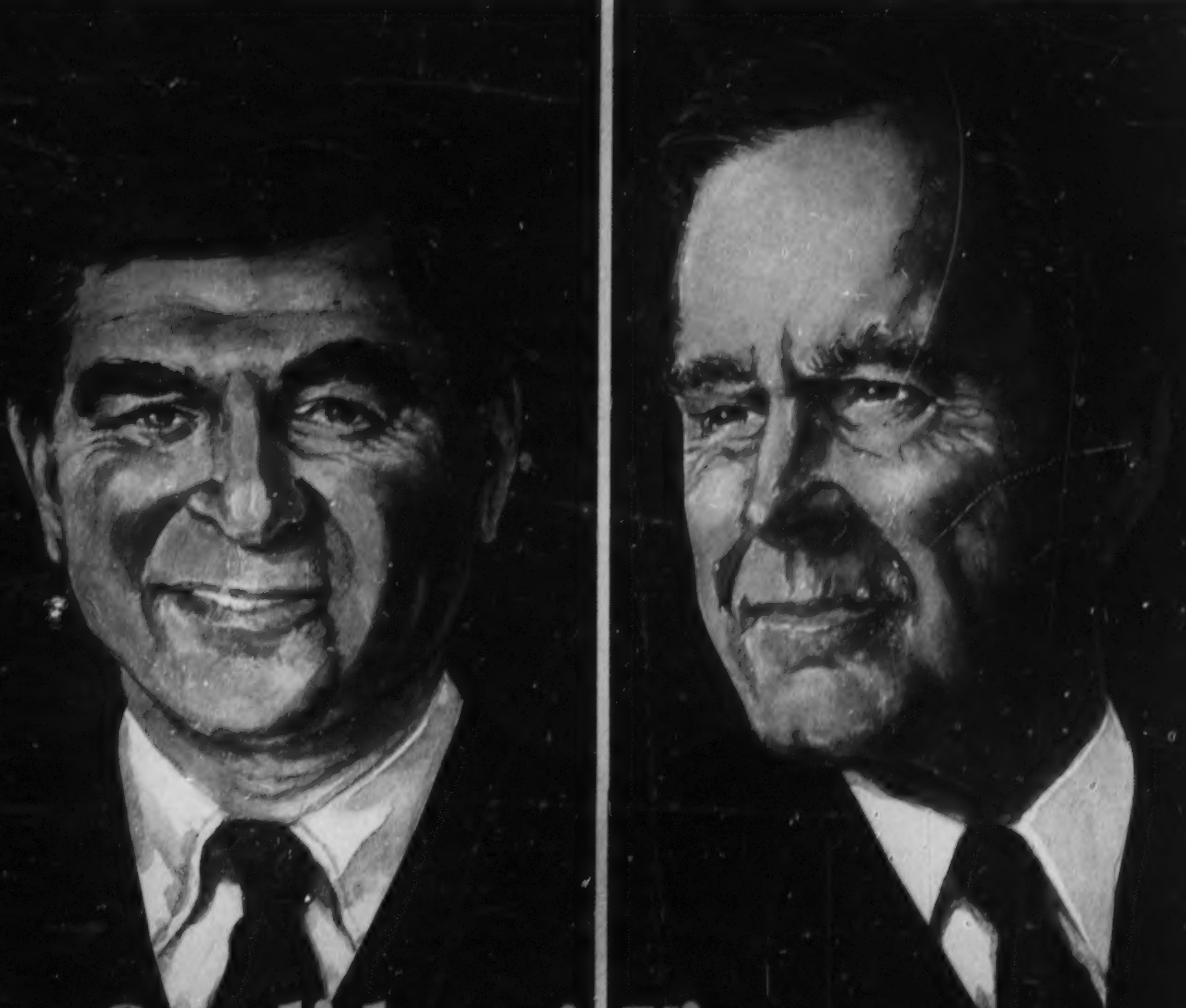
41250-1
10/20/88

More scientific news from Los Angeles ACS meeting

OCTOBER 17, 1988

CHEMICAL & ENGINEERING

NEWS



Candidates' Views

Dukakis and Bush discuss science issues

Page 7

0511179C099 9 K AR6642SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Volume 66, Number 42
CENEAR 66 (42) 1–64
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

OCTOBER 17, 1988

News of the Week

- **One year after Black Monday's stock market crash, chemical stock index outperforms major indexes. Page 4**
- **AIDS activists demonstrate at FDA headquarters in Rockville, Md., angrily attack pharmaceutical clearance, testing policies. Page 5**
- **First commercial license of superconductivity technology by federal lab is granted to Massachusetts firm. Page 5**
- **MIT celebrates centennial of the founding of chemical engineering course. Page 6**
- **Department of Energy announces plans to speed startup of Savannah River nuclear reactors, shut down since August for safety reasons. Page 6**

Business

Responses to current chemical industry challenges—recruitment of personnel, improving product quality, and the internationalization of markets, among others—were discussed at the recent meeting of the European Section of the Society of Chemical Industry. **Page 16**

Government

From the ACS meeting in Los Angeles: The admissibility of DNA test results as legal evidence is debated at a symposium sponsored by the Division of Chemistry & the Law. **Page 19**

Education

From the Los Angeles meeting: Educators suggest changes to the general chemistry curriculum; universities respond to increasing need for biochemical engineers with an expanding number of undergraduate and graduate course offerings. **Page 25**

Technology

Also from Los Angeles: Efforts intensify to develop erasable optical media for data storage and retrieval; chemical sensors play increasing role in analytical instrumentation; importance of catalysis in direct coal liquefaction detailed; advances made in processing conducting polymers. **Page 30**

ACS News

Council acts on petitions, variety of other matters at Los Angeles meeting; ACS presents first-ever Phoenix Awards to local sections and individuals for their participation in National Chemistry Day.

Page 40

Letters	2
Concentrates	
Business	12
Government	18
Science/Technology	24
The Departments	
Meetings	43
Newscripts	64

CAMPAIGN
88

News Focus

Presidential candidates George Bush and Michael Dukakis respond to C&EN questions on research funding, environmental concerns, science education, and other science issues. Page 7

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Ann M. Thayer (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 63)

LETTERS

Valid public concerns

SIR: This is in response to R. Thomas Myers' letter (C&EN, July 18, page 2) under the heading, "Environmental issue." Although I agree, in general, with Myers' description of the four phases of industrial environmental concern and reaction, the key phrase, in his reference to a previous letter in C&EN by Robert D. Kennedy (C&EN, May 23, page 3), is "valid public concern."

Just what constitutes a valid concern is usually the thorny part of these issues; for example, valid by what and whose criteria? Is the fluoride ion-drinking water issue a valid concern? Is the use of animals for the testing of drugs and pharmaceuticals a valid concern?

I feel that during Myers' "phase 1" and "phase 2," the chemical industry is (again, speaking generally) attempting to determine logically the true validity of the public concern(s). Our growing public chemophobia must be met with scientific patience, respect, and reasoning and not with panic and overreaction.

Richard D. Stacy
Tucson, Ariz.

First chemistry encounter

SIR: I was surprised, though not a lot, to read the comments addressed to the Carleton College Conference of the Council on Undergraduate Research by Erich Bloch, director of the National Science Foundation (C&EN, Aug. 8, page 28). Though most engineers may end formal education with the bachelor degree, such is certainly not the case with chemists. It is almost entirely untrue when one considers the careers of those carrying out research in universities or in industry. Though it is, in the abstract, a danger that small schools in the U.S. might think research more important than teaching in some far-off future, the danger is so remote that we needn't worry about it in this century or the next. What we do need to worry about is the ever-decreasing supply of American undergraduates choosing professional careers as research chemists. In that context, the smaller non-Ph.D.-granting institutions play a most important role, and undergraduate research is their bread and butter.

Anyone who has participated in the preprofessional education of chemistry students knows how significant an undergraduate research experience can be for the students who claim they wish to be chemists. It provides a young person with the first real encounter with what it means to be a chemist. Some thrive, some flounder. But in discovering that not every problem has a right answer, or any answer, the student encounters valuable lessons. Undergraduate research also provides chemistry majors with identity—an identity with the subject and with the profession. This, too, is valuable, for it gives the group of chemists-to-be a spirit and a closeness to the subject. In smaller colleges, undergraduate research is the only game in town. Faculty members in four-year and non-Ph.D.-granting institutions desperately need it to survive intellectually over the course of their careers. That they are able to nurture their own intellectual curiosity and provide undergraduates with exciting, almost tutorial instruction, is also extremely important and of added benefit to the profession. This faculty interest alone can, at times, encourage a young person to consider a career in our subject rather than another. Above all, however, undergraduate research is the one unique way that U.S. colleges and universities can encourage the scientifically skilled to choose chemistry as a career. There's nothing wrong with that as near as I can tell. Chemistry remains an experimental science, and the only thing we have going for us as a discipline that differs from any other is the experimental laboratory work, which is the unique domain of our chosen profession.

In recent years the National Science Foundation, National Institutes of Health, and the Department of Defense have all recognized the value of research with undergraduates and research in predominantly undergraduate institutions by establishing new programs—rather small by their standards—to support projects and people in four-year colleges and non-Ph.D.-granting schools. These important steps

Corrections

- Sept. 19, page 18: Avtex Fibers sold its interest in a South African wood pulp operation to a consortium represented by Sappi Ltd., a publicly owned South African pulp and paper producer, not to the South African government.

- Sept. 12, page 29: The Engineering Research Center for Advanced Electronic Materials Processing is located at North Carolina State University, Raleigh, under the direction of Nino A. Masnari.

STOCK MARKET:
Chemicals outperform other issues

Shortages of basic chemicals such as ethylene, styrene, and caustic soda, stable or lower feedstock prices, and a weak U.S. dollar that has helped increase overseas demand for U.S. chemicals have recently helped increase many chemical companies' sales and profits, and to some extent their stock prices.

Chemical stock prices, as measured by the C&EN stock price index, have advanced more than 24% above closing prices a year ago on Black Monday, Oct. 19, 1987. On that day, the market crashed and the Dow Jones Industrial Average declined 508 points, almost 23%.

The situation looked baleful then, when the C&EN index dropped 107 points, or 20% on the day, to 423 (1957 = 100). But as of Oct. 7 this year, this index has recovered to within a few points of its close on the Friday before Black Monday.

The chemical index, however, is currently 20% below the 1987 high of 630, attained on Oct. 2, just 17 days before the crash. The C&EN index is based on the weighted market value of the stocks of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide.

However, although business may be good for commodity chemical makers, producers of many downstream products such as polyester fiber are unable to raise prices fast enough to preserve their profit margins. And fears that an increase in the number of basic chemical plants planned for the near future will ~~produce a glut~~ of basic petrochemicals have discounted the price that skittish investors will pay for the stocks of commodity producers at this late stage of the commodity chemicals market cycle.

The high prices investors were willing to pay in early October 1987 for many chemical company stocks may have been an anomaly. It was an unrealistic and euphoric outlook that drove the Dow Jones average to a high of 2709 on Aug. 21, 1987. Presumably driving this climb was the theory that U.S. assets were undervalued relative to their valuation in Japan, and the belief that the Japanese would continue to finance not only the market's rise but also the national debt. Chemical companies benefited from much the same euphoria, and suffered much the same drop in valuation as the whole market when that market psychology changed.

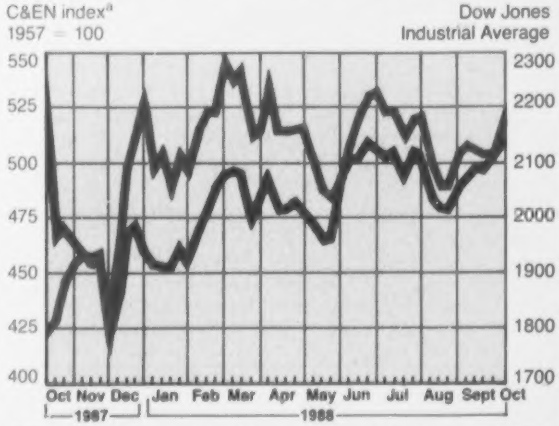
C&EN's chemical stock index shows that the market has valued its underlying stocks at least marginally better than those on the Dow Jones average (which is up almost 24%) and the New York Stock Exchange Composites Index (up 22%). And chemical stocks have done appreciably better than the securities represented in the Over-the-Counter Industrials Index (up 3.6%), as well as the Over-the-Counter Composite Index (up 7.1%).

Marc Reisch

Chemical stock index outperforms other major indexes

	Oct. 19, 1987	Oct. 7, 1988	% change
C&EN chemical stock index	423	525	24.1%
Dow Jones Industrial Average	1738.74	2150.25	23.7
New York Stock Exchange Composite	128.62	156.81	21.9
New York Stock Exchange Industrials	153.47	188.82	23.0
American Stock Exchange Index	282.50	303.82	7.5
Over-the-Counter Composite	360.21	385.67	7.1
Over-the-Counter Industrials	369.73	383.19	3.6
Standard & Poor's 500	224.84	278.07	23.7
Standard & Poor's 400 Industrials	257.81	319.17	23.8

Chemical stocks have outperformed major industrial stocks since October crash

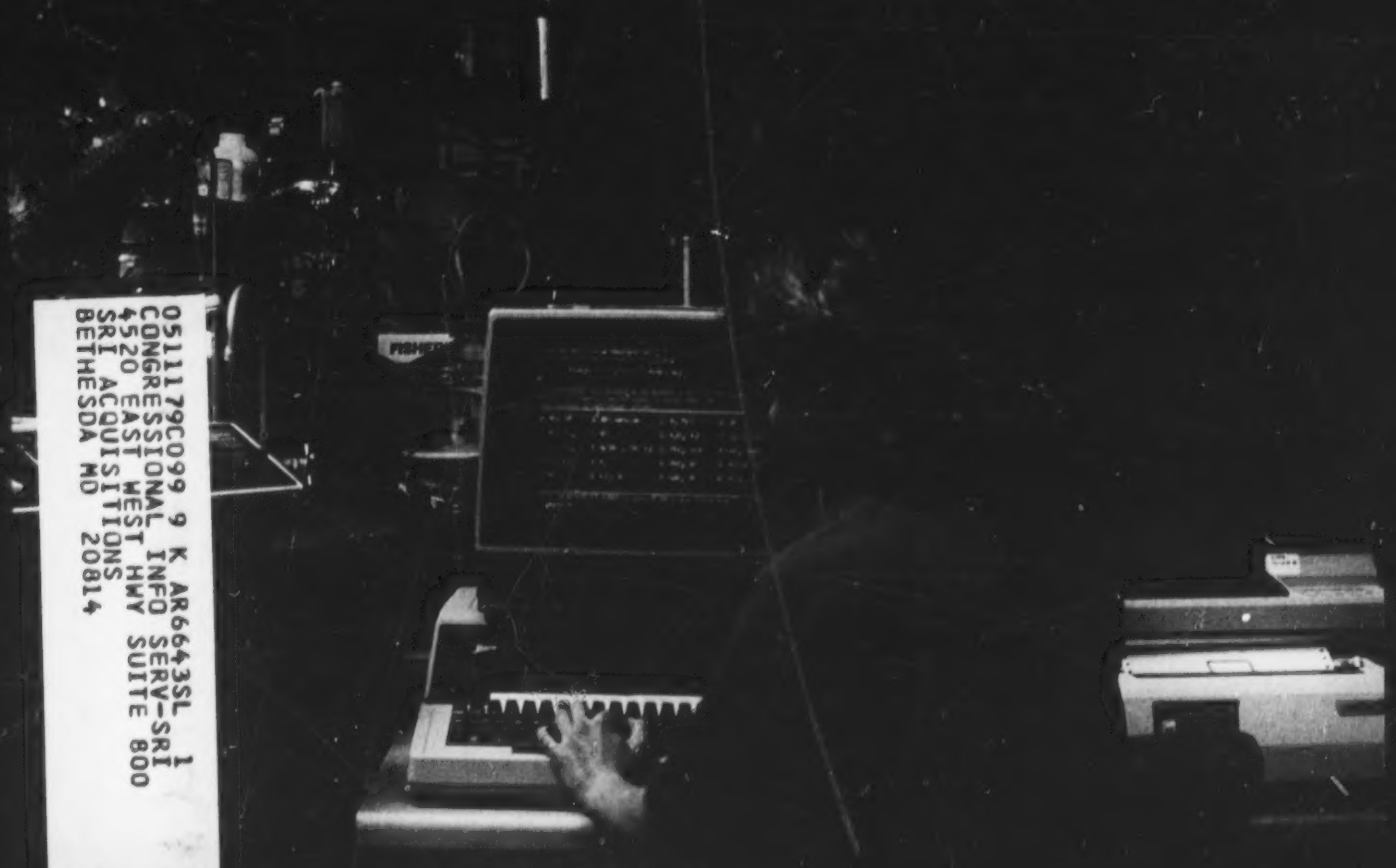


a C&EN weighted stock price index of American Cyanamid, Dow Chemical, W. R. Grace, Hercules, Monsanto, Rohm & Haas, and Union Carbide.

41250-1
10/26/88

OCTOBER 24, 1988

CHEMICAL & ENGINEERING NEWS



0511179C099 9 K AR6643SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

1989 Employment Outlook

Computers offer wide potential
for undergraduate education
Page 29

CHEMICAL & ENGINEERING
NEWS

Volume 66, Number 43
CENEAR 66 (43) 1–84
ISSN 0009-2347

OCTOBER 24, 1988

News of the Week

- **Three West German researchers win Nobel Prize in Chemistry for their work on photosynthesis; two Americans and a Briton win prize in medicine for drug research; and physics prize goes to three U.S. scientists for neutrino studies.** Page 4
- **The French government launches a study of the country's chemical industry to evaluate the need for structural changes in light of move to unify European Community market in 1992.** Page 5
- **Hercules is commercializing a food packaging system that will extend the shelf life of fresh fruits and vegetables.** Page 6
- **Earnings rose once again for major U.S. chemical companies in the third quarter, although rates of increase have slowed from previous quarters.** Page 6

Cover: University of Kansas student uses computer-assisted instruction program in organic chemistry. Photo by Robin Loomis Kern

Letters 2

Concentrates

Business 7
Government 15
Science/Technology 20

The Departments

ACS Focus 52
ACS News 54
New Products 61
People 62
Newscripts 84

Business

Ethyl *tert*-butyl ether may find use as an octane enhancer, if favorable ethanol feedstock prices can be obtained; BASF's Geismar, La., amines plant was built to protect market share; European Chemical Marketing Research Association meeting examined the chemical industry outside Western Europe, with the U.S.S.R., Japan, and South Korea particularly drawing interest. **Page 11**

Government

Pirating of U.S. patented chemicals in foreign countries continues to be a perplexing problem, but the industry is working hard to find solutions; Federal Laboratory Consortium for technology transfer promotes the rapid movement of research results from federal labs to the private and public sectors. **Page 16**

Education

Chemical engineering education celebrates centennial as profession faces global challenge in a changing world. **Page 21**

Science

Solid sodium chloride can affect atmospheric chemistry. **Page 22**

Technology

Polyurethane foams industry looks to promising alternatives to currently used chlorofluorocarbon blowing agents; method prepares particles with apparent cluster/colloid duality. **Page 23**

Books

"**Acid Rain: Rhetoric and Reality,**" by Chris C. Park, addresses still-raging political and economic battles; second edition of "Hazardous and Toxic Materials" updates readers on important developments. **Page 49**

Employment Outlook

C&EN's annual look at the job market focuses on innovative computer techniques that can be used to help undergraduate students learn skills they will need in graduate research and in their careers. **Page 29**

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Ann M. Thayer (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager). Alan Kahan (Art Director). Barbara Fryer (Production/Art Director). Linda Mattingly (Staff Artist). Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel; *President:* Gordon L. Nelson; John H. Nelson; Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210; (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign; more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 83)

LETTERS

Benzene rings

SIR: The picture of benzene bonded to a rhodium surface and captioned "Benzene snapshot captures images of individual rings" (C&EN, Aug. 1, page 5) was very intriguing.

However, if the communication by Parker, Hexter, and Siedle, "Surface Conversion of Benzene to Acetylene," in the *Journal of the American Chemical Society* [**107**, 4584 (1985)] is correct, the addition of a pi-acceptor, such as carbon monoxide to stabilize benzene on the surface, resulted in a loss of resonance stabilization energy by the benzene and was balanced by the increased metal-carbon sigma bonding (two electrons to rhodium from the acetylene) and pi back-bonding in the three acetylenes and the rhodium. Therefore, the appearance of three two-atom clusters in the picture may be explained as acetylenes bonded to rhodium.

Jeffrey L. Moler
Research Chemist
James R. McCoy
Technical Area Manager
Aero Propulsion Laboratory
Wright-Patterson Airforce Base

Efforts to reduce cancer

SIR: Regarding John C. Bailar's article, "Rethinking the War on Cancer" in *Issues in Science and Technology*, and Ernest Volkmann's knowledgeable letter of response (C&EN, Aug. 8, page 3), we may be looking in the wrong place.

Several weeks ago I attended a conference sponsored by the Fetzer Foundation and others in Kalamazoo, Mich., and was introduced to the term psychoneuroimmunology. It is indeed a mouthful, but as a field of study it takes its premise from the research on the human immune system, on the brain's role in influencing this system, and, most important, the psychological state of the individual in this whole affair.

As I understand it from listening to several speakers (whose names, unfortunately, I do not recall), each of us can influence our own immune system by our beliefs, thoughts, feelings, and general psychological state. We do this continuously and more-or-less unconsciously. However, the result is that our immune systems respond by raising or lowering our resistance to viruses and other potentially harmful organisms. Thus our psychological state may well be a major factor in determining who gets cancer and who recovers or does not.

I understand that there is some research to support this, although it is still very new. Perhaps others in ACS can provide more specific information.

In any event, if the research supports the contention of the psychoneuroimmunologists, then at least we have a complementary perspective on the etiology of cancer and related diseases, and we might even find that our well-meaning efforts to reduce cancer by enlightening the general population on the subject induce enough fear and anxiety to accomplish the opposite. It is a sobering thought.

C. Philip Alexander
Ann Arbor, Mich.

Tax reform casualty

SIR: The letters from postdoctoral fellow Sheri L. Blystone (C&EN, June 27, page 2) and Pennsylvania State University graduate students Donald Cronce, Susan Ensel, and John Sczepanski (C&EN, April 25, page 3) have compelled me to share my tax burden plight with C&EN readers. I, too, am prompted to share my concerns about the 1986 National Tax Reform Act. I have fallen victim to it.

After finishing my Ph.D. in the fall of 1986, I served the state of Connecticut by accepting the first postdoctoral fellowship sponsored by the Connecticut Department of Health in cooperation with the University of Connecticut Institute of Water Resources. I designed and implemented a project on analysis of suspected cancer-causing compounds in Connecticut drinking water. During November and December 1986 my fellowship income was tax free. However, recently I found out (as did millions of others) that the tax laws had changed and that the fellowship payments I received in 1987 were now taxable. At the time, I was told by the University of Connecticut not to worry about filing a W-2 for the 1987 calendar year because the award was a fellowship. I now owe the IRS $1800 in back taxes and am in the process of paying the IRS $200 a month for nine months. I don't own a home, I'm married with one child and have another one on the way. To me, $200 a month is a lot of money. I left Connecticut and took a position in the

Correction

- Oct. 3, page 16: 100 to 125, not 100,000 to 125,000, cu ft of methane is required to make 1 gal of methanol in a plant using Lurgi technology similar to that used in Tenneco Oil's plant

U.S.S.R., Far East offer challenges to Western firms

Patricia L. Layman, C&EN London

With its theme of global issues and the chemical industry, the meeting earlier this month in Rome of the European Chemical Marketing Research Association looked at how global demand is changing the supply and marketing patterns for a number of industry sectors. It also proved an opportunity for the nearly 250 attending the conference to examine the chemical industry outside the bounds of Western Europe. The Soviet Union, in the midst of political change and restructuring (C&EN, Jan. 18, page 28), and the Far East, particularly Japan and South Korea, were of particularly high interest.

Despite the changing political climate in the Soviet Union, the Western company wishing to do business in the Soviet chemical sector would be well advised to remain resolutely realistic and keep a very long-range timetable, said Paul Zieber, head of the Hamburg-based Institute for Market Research in Eastern Europe.

According to Zieber, the Soviets now consider their chemical industry in two major sectors. One will have very little or no growth: most mineral mining products, chlorides, nitrogen, and commodity pesticides. Growth will be limited, in part, he pointed out, because of pollution concerns. The other sector will exhibit strong growth: plastics, synthetic fibers, synthetic rubber, tires, paints and lacquers, phosphate fertilizers, biological pesticides, and pharmaceuticals.

Petrochemicals will continue to be the center of development of the Soviet chemical industry until the year 2000, with oil and gas no longer considered "combustibles" but chemical raw materials. Major end uses will be the plastics industry, which will see massive development.

The Soviet chemical industry has already invested significant sums in development, but—according to Zieber's analyses—major proportions of those sums have gone into industrial equipment that has never been started up. Many chemical plants, he said, have never been put into operation, even after 10 years, or if they have been, are running at as low as 30% of capacity.

That dismal record has led to the Politburo decision, he added, that from now on, all investment plans that include Western technology are to be built by joint ventures. "In a joint venture, it is assumed that Western businessmen won't wait for years to bring a plant on stream—they will insist everything is hooked up, to come on stream."

The stated goal of the Soviet Union is to cut exports of basic chemicals, and begin exporting their higher-value-added derivatives. Until then, however, the pattern probably will remain similar to the current one. The U.S.S.R. imports roughly $4 billion of chemicals—specialty chemicals and basic chemicals in which the Soviets are short of capacity—and exports only $1 billion, generally basic chemicals—ammonia and petrochemicals.

The new plants planned will depend on the massive petrochemical complexes the U.S.S.R. is building. Joint ventures are important for these. There is one, for example, between the Ministry of the Petroleum Refining & Petrochemical Industry and Combustion Engineering and McDermott, to build petrochemical centers in western Siberia for producing aromatics, derivatives of aromatics and olefins, specialty rubber, alcohols, plastics, and lubricants. Another is planned with possible partners Chevron and Du Pont, and yet another with Occidental Petroleum, ENI and Montedison of Italy, and Marubeni of Japan.

What does the Soviet interest in joint ventures mean for the Western chemical industry? One answer came from Trevor Waldron, business development director at Monsanto Europe, who pointed out that Monsanto has been doing business since the 1950s in the Eastern bloc. The initial deals were with rubber vulcanization chemicals for auto tires, and have been extended to include agrochemicals, acrylonitrile-butadiene-styrene plastics, and various industrial chemicals.

The growing demand for and emphasis being placed on consumer products will mean a continuing demand for Western specialties, for end uses such as automotive, food packaging, and medical. The Soviets are working, Waldron said, to bring on stream their own capacity in the chemicals that will be needed, but "they will find it is just not possible to orchestrate the balanced development of specialty chemical production overnight."

Business in the chemical sector is also increasingly dependent on environmental qualities, he added, as the Soviets turn their attention to an area sadly neglected until recently. Monsanto has been negotiating a joint venture to produce herbicides since last year from its Moscow office, which Waldron anticipates expanding in personnel 20% per year for the next few years. According to Waldron, "Our potential partner's first question was not 'What's the process?' or 'How much does the plant cost?' It was 'What are the effluent and emission outputs?' It's an extremely hot issue, and there is a great deal of ground to cover."

Some 300 Soviet organizations are looking for foreign joint-venture partners, in addition to those already involved in the 500 or so joint-venture evaluations currently being conducted, and the nearly 100 already formed. However, he added, they can pose problems: "The objectives must be at least complementary, and that is difficult. The Eastern Europeans want technology and

Soviet demand for plastics set to grow quickly

Thousands of metric tons	1985	1990	1995	2000
Polyethylene	1102	1592	3,079	4,800
Polypropylene	93	213	641	1,000
Polystyrene, copolymers	466	610	1,010	1,400
Polyvinyl chloride, copolymers	455	815	1,355	2,200
TOTAL	2116	3230	6,085	9,400
TOTAL ALL PLASTICS	5019	7100	11,914	17,200

Source: Institute for Market Research in Eastern Europe a means to earn foreign currency. We Westerners tend to just want a foothold in potentially massive markets."

Besides the usual preparation and the customer analyses needed, Waldron added, "It takes a lot of patience. They are usually big customers, and they know it. They are suspicious of 'capitalist' companies. You need to be prepared to invest a lot of time and money to build business." And it is important to participate in trade fairs and seminars, which are especially important to Socialist customers because they offer "neutral territory," according to Waldron. "It's not your office, or their ministry, and it is a more relaxed atmosphere than the typical business meeting."

Offering different kinds of challenges to Western chemical companies are the industries in South Korea and Japan.

Japanese investment in the chemical industry outside its borders has been slowly growing since the early 1980s, but still amounts to only about 10% of the $3.8 billion invested overseas by Japanese firms in 1986, said Takao Ayabe, executive managing director for Mitsui Toatsu Chemicals, Tokyo. On the other hand, in 1987, the stock price as a multiple of earnings was four or five times higher for Japanese chemical companies than for their counterparts in the U.S. or Western Europe, he pointed out. That makes acquisition of Japanese chemical companies prohibitively expensive.

Where U.S. and West European chemical companies have entered Japan, instead, is in the field of "leading-edge technologies," Ayabe noted. "By constructing factories and research facilities in Japan, European and American companies are demonstrating their growing commitment to the Japanese market." Examples he cited of such facilities included those of Bayer, Du Pont, Hoechst, ICI, and Monsanto.

The petrochemical sector, on the other hand, would hardly be attractive for Western industry. The Japanese chemical industry has gone through severe restructuring, with major capacity shutdowns throughout the industry. For example, between 1982 and the middle of this year, the industry, goaded by the Ministry of International Trade & Industry, cut ammonia capacity 40%, ethylene capacity 32%, polyolefin capacity 21%, polyvinyl chloride capacity 22%, ethylene oxide capacity 16%, and styrene capacity 19%, he said.

South Korean consumption of plastics to rise markedly

Thousands of metric tons	1977	1987	1997
Polyethylene	169	612	1318
Polypropylene	123	387	677
Polystyrene, copolymers	44	386	827
Polyvinyl chloride copolymers	145	380	837
TOTAL	481	1765	3659
TOTAL ALL PETROCHEMICALS	892	2928	5[illegible]2

Source: Yukong Ltd.

In the South Korean marketplace, on the other hand, producers have set their own expansion plans. Overcapacity likely will be the result, said J. R. Park, vice president for chemicals business at Yukong Ltd., the Seoul-based oil company.

The South Korean industry has had the unfortunate history of completing major chemical investments just when world economies go into recession, Park pointed out—a history that he hoped will not repeat itself as the industry is completing another building round. Encouraged by the government to expand petrochemical production in the 1960s as a means to cut imports, the chemical industry expanded production from roughly 15,000 metric tons in 1962 to 290,000 metric tons in 1972. The next round of expansions took place through the end of the 1970s, when demand growth rates in major petrochemical products were running anywhere from 15 to 26% per year.

As Ayabe observed, by 1980, "The industry was in dire need of rationalization measures, and restructuring had to be contemplated." Since then, however, growth has returned to the industry, enough to encourage a third round of major expansions, in what Park called "overheated investment in petrochemicals."

For example, current ethylene capacity in South Korea is 505,000 metric tons per year. Three additions or expansions are under way with startups scheduled between August 1989 and December 1991, to bring the total to 1.51 million metric tons per year. Moreover, said Park, plans for seven more ethylene plants have been announced, believed to be backward integrations or new entrants to the market, which would add yet another 2.25 million metric tons.

Also, ethylene producers have decided to integrate forward by adding polymer capacity. Existing capacity for polyethylene in South Korea is 445,000 metric tons. Another 340,000 metric tons is being added by existing producers, and seven companies have announced plans for capacity that will tack on another 852,000 metric tons per year.

In polypropylene, in which South Korea is already a net exporter, expansions are currently under way that will lift capacity from 450,000 metric tons to 610,000 metric tons per year. Announcements of polypropylene expansion plans from nine companies would add 1.07 million metric tons per year. Three of those new projects would be based on propylene derived from propane dehydrogenation in South Korea, said Park.

"The petrochemical industry in South Korea, albeit its structural problems, is a growing industry," he said, that will continue to grow through the late 1990s, when it will mature. Among the positive factors for the industry is its geographic proximity to "the huge unexplored markets—China and North Korea." It is clear, however, that South Korea will be a significant exporter of petrochemicals, particularly of polyolefins and polystyrenics, when all the expansions are completed. Until then, almost all petrochemicals, including ethylene and propylene, will have to be imported in "sizable volumes."

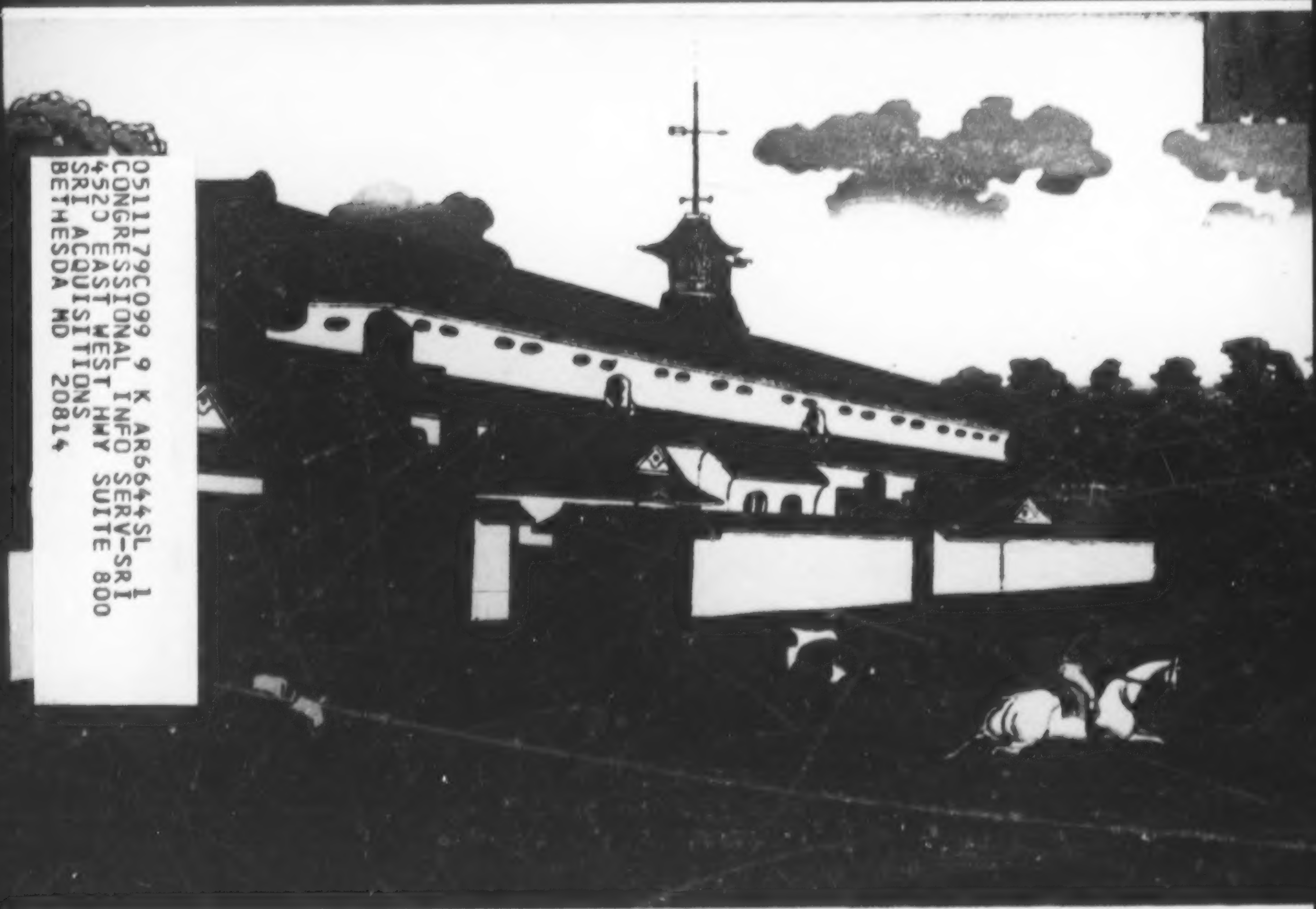
In other chemical industry sectors, he added, "there are innumerable vacancies in the petrochemical industry chart, and potential joint-venture partners and technology licensees can be located," offering business opportunities for Western companies. □

41250-1
11/4/88

Research on medical uses of metalloporphyrins advances
Page 18

OCTOBER 31, 1988

CHEMICAL & ENGINEERING NEWS



0511179C099 9 K AR6644SL 1
CONGRESSIONAL INFO SERV-SRI
4520 EAST WEST HWY SUITE 800
SRI ACQUISITIONS
BETHESDA MD 20814

Western Chemistry Comes to Japan:
A Historical Account Page 26

Volume 66, Number 44
CENEAR 66 (44) 1–68
ISSN 0009-2347

CHEMICAL & ENGINEERING NEWS

OCTOBER 31, 1988

News of the Week

- **Congressional task force suggests ways the government and Congress can help U.S. industry regain its competitive edge in technology both domestically and globally.** Page 4
- **The Soviet Union has granted physicist and human rights leader Andrei D. Sakharov permission to visit the U.S. next week.** Page 5
- **Ciba-Geigy's request for a permit to build a drug plant at its Toms River site has been turned down by the New Jersey Department of Environmental Protection because of toxic waste problems at the site.** Page 5
- **Procter & Gamble plans to test market a plastic bottle made from recycled polyethylene terephthalate.** Page 6
- **Atlantic Richfield may spin off its Lyondell Petrochemical subsidiary into a publicly held company.** Page 6

Cover: The Seimikyoku ("school of chemistry") established by Koenraad Gratama at Osaka, Japan, in 1869 is depicted in a woodblock print by Sadanobu Hasegawa

Letters 2
Concentrates
Business 7
Government 11
Science/Technology 17
The Departments
ACS News 48
People 50
Newscripts 68

Business

Increasing demand for styrene triggers spate of plans for capacity expansions that will add at least 3.3 billion lb by 1992. Page 9

Government

End-of-session Congressional actions of interest to the chemical community include enactment of a drug bill, a tax bill that extends the R&D tax credit, and NSF's authorization bill. Page 12

Congress and the Reagan Administration initiate a number of new programs to fight the AIDS epidemic. Page 16

Science

Metalloporphyrin research makes strides in biomedical applications with ^{67}Cu- and ^{10}B-labeled molecules among compounds showing promise in diagnostic imaging and cancer therapy. Page 18

Cleaner route to cyclic sulfate esters of 1,2-diols developed by chemists at Massachusetts Institute of Technology. Page 22

Technology

Researchers discover catalysts that enable heterocyclic olefins to polymerize more readily in water than in organic solvents. Page 23

A number of new hardware and software products were introduced at the recent ACS exposition in Los Angeles. Page 24

Books

"**Interactions:** A Journey Through the Mind of a Particle Physicist and the Matter of This World," by Nobelist Sheldon L. Glashow, fails as both interesting autobiography and particle physics primer. Page 42

Special Report

日本の化学

The introduction into Japan of western-style chemical education and industrial-scale chemical production was accomplished by Dutch physician/chemist Koenraad Gratama, who died 100 years ago. Page 26

Chemical & Engineering News

1155—16th St., N.W., Washington, D.C. 20036

Editor: Michael Heylin
Assistant Managing Editors: David M. Kiefer, James H. Krieger, Janice R. Long, Donald J. Soisson, William J. Storck. **News Editor:** Wilbert C. Lepkowski
Staff Editor: Ernest L. Carpenter
Senior Editors: New York: Earl V. Anderson, Stephen C. Stinson; Chicago: Joseph Haggin; Washington: Doron Dagani, Lois R. Ember, Rebecca L. Rawls, Pamela S. Zurer
Associate Editors: Stuart A. Borman, Mairin B. Brennan, Bette Hileman, Richard J. Seltzer
Service Departments Editor: Dolores Miner
Editing Services: Anne Riesberg (Head), Arlene Goldberg-Gist (Editorial Assistant), Patricia Oates (Administrative Assistant)

News Bureaus: Northeast News Bureau: (201) 906-8300 Marc S. Reisch (Assistant Editor), Ann M. Thayer (Assistant Editor), Rachel Eskenazi (Administrative Assistant). Chicago: (312) 256-4143 Ward Worthy (Head). Houston: (713) 973-8161 Bruce F. Greek (Head). Washington: (202) 872-4495 David J. Hanson (Head). West Coast: (415) 653-3630 Rudy M. Baum (Head). **Foreign Bureau:** London: (01) 540-0414 Dermot A. O'Sullivan (Head), Patricia L. Layman (Associate Editor)
Graphics and Production: Leroy Corcoran (Manager), Alan Kahan (Art Director), Barbara Fryer (Production/Art Director), Linda Mattingly (Staff Artist), Diane Kelly (Costing). **Business Manager:** Arthur Poulos
Circulation Development: Claud K. Robinson

ADVISORY BOARD: William J. Bailey, Jacqueline K. Barton, Ernest H. Drew, Harry G. Drickamer, A. Nicholas Filippello, Vincent L. Gregory Jr., Adam Heller, John D. Holmfeld, Isabella Karle, Koji Nakanishi, Richard Nicholson, Howard A. Schneiderman, Ellen K. Silbergeld, Howard E. Simmons, Robert M. Simon, William P. Slichter

Published by
AMERICAN CHEMICAL SOCIETY
(202) 872-4600; TDD (202) 872-8733
John K Crum, Executive Director

PUBLISHING BOARD: Ned D. Heindel (*Chairman*); *Board of Directors Chairman:* Ernest L. Eliel, *President:* Gordon L. Nelson, John H. Nelson, Louis D. Quin; Jean'ne M. Shreeve; and Barbara G. Wood

© Copyright 1988, American Chemical Society

Subscription & Member Record Service: Send all new and renewal subscriptions with payments to: Controller, ACS, P.O. Box 28597, Central Station, Washington, D.C. 20005. Correspondence and telephone calls for changes of address, claims for missing issues, subscription service, status of records and accounts should be directed to: Manager, Membership & Subscription Services, ACS, P.O. Box 3337, Columbus, Ohio 43210, (614) 421-3776.

For changes of address, include both old and new addresses with ZIP code numbers and mailing label from a recent issue. Allow four weeks for change to become effective. Claims for missing numbers will not be allowed if loss was due to failure of notice of change of address to be received in the time specified; if claim is dated (a) North America: more than 90 days beyond issue date, (b) all other foreign: more than one year beyond issue date; or if the reason given is "missing from files."

Subscription Rates 1988. Printed editions: nonmembers U.S. 1 yr. $49, 2 yr. $83, outside U.S. 1 yr. $75, 2 yr. $135. Air freight rates available on request. Rates above do not apply to nonmember subscribers in Japan, who must enter subscription orders with Maruzen Co. Ltd., 3-10 Nihonbashi 2-chome, Chuo-ku, Tokyo 103, Japan. Tel: (03) 272-7211. Single copies: Current $7.00. Rates for back issues and volumes are available from Microforms & Back Issues Office, ACS, 1155—16th St., N.W., Washington, D.C. 20036. Back and current issues available on microfilm and microfiche. Rates on request from Microform Program, ACS.

Chemical & Engineering News (ISSN 0009-2347) is published weekly except for the last week in December by the American Chemical Society at 1155—16th St., N.W., Washington, D.C. 20036. Second-class postage paid at Washington, D.C., and additional mailing offices. POSTMASTER: Send address changes to Chemical & Engineering News, Membership & Subscription Services, P.O. Box 3337, Columbus, Ohio 43210. ACS assumes no responsibility for the statements and opinions advanced by the contributors to its publications.

Advertising Management
CENTCOM LTD.
(For list of offices see page 67)

LETTERS

Chemists in the popular press

SIR: An article in the Oct. 4 issue of the *Arkansas Gazette* summarized a number of major breakthroughs announced at the national ACS meeting in Los Angeles. This is the first time that I can recall seeing such an article in the popular press, except for articles in the cities where meetings are held. The article, which had a Gannett News Service byline, described genetic fingerprinting, a new cancer therapy, superconductor advances, and an artificial lens for eye implantation. These are topics that catch the attention and imagination of the public. Although it is gratifying to see an article highlighting an ACS meeting, it is disturbing to realize that only one time are chemists mentioned. Nowhere in the article are chemists given credit for the contributions that they have made to these fields.

There is a need for more articles in the popular press highlighting the accomplishments of chemists and chemistry. This is not just to pat ourselves on the back. The prosperity of our society depends on continued technological advances. The quality of science and engineering students seems to be gradually falling. This may be because salaries and prestige have fallen behind that of many medical and business professions. Few people have any idea what chemists do. No student is going to consider entering a field about which he or she knows nothing. One way to convince bright students that chemistry is a viable career choice is to show them what chemists are accomplishing today, at the forefront of technology. ACS simply must become more effective at getting the national press to recognize these accomplishments.

But, it is not only up to the national ACS. Each member and each section has a role to play also. Last November this institution hosted the Ouachita Valley Section's National Chemistry Day program. We worked hard to make it a success. Hundreds of school children, college students, and members of the general public had an opportunity to see some of the ways that they benefit from chemistry. The resulting newspaper and television coverage brought a positive impression of chemistry to many more. In talking with members of other sections, I was very disappointed to find that few other sections in this area did anything to promote chemistry to the general public.

As individuals there is much that we can do. Our chemistry faculty members frequently perform demonstrations in public schools in a 10-county area. This is obviously a recruiting effort, but we also expose many students to the fun side of chemistry. We take every opportunity to perform demonstrations during campus events such as parents' day and homecoming, just to present a positive image of chemistry to a portion of the general public.

The attitude of many academic chemists is, "Leave me alone and let me do my research." The irony is that unless the general public, state legislatures, and Congress are convinced that what we do is meaningful, research funds will eventually dry up. It is up to chemists, individually and collectively, to promote our science, which has benefited so many people in so many ways. We must do a better job.

Thomas A. Ekman
Assistant Professor of Chemistry
Southern Arkansas University

Erroneous data

SIR: I am writing to correct erroneous data in the report on facts and figures for chemical R&D (C&EN, Aug. 22, page 29). The table on page 63 bears the headline, "University of Texas makes big jump into top 10," and the data contained in the table indeed show a change in rank from 27th to fifth in spending on chemical R&D.

This impressive leap is actually the consequence of propagation of an error in the data on which the report for 1985, published in the July 27, 1987, issue of C&EN, was based. As noted in a letter published in C&EN last fall, our total research funding in that reporting year was $7.908 million so that our ranking actually should have been sixth rather than 27th. UT Austin thus has moved up only one place in the rankings rather than the 22 places indicated. Given the corrected figure for 1985 research funding, the annual change from 1985 to 1986 is 8% rather than the 86% shown in the table.

The table on page 64 also reflects the erroneous reporting for 1985. Our feder-

Correction

- Sept. 19, page 16: Courtaulds sold its interest in a South African wood pulp operation to a consortium represented by Sappi Ltd., a publicly owned South African pulp and paper producer, not to the South African government.

Strong Demand for Styrene Spurs Capacity Expansion

Spate of plans announced by four of eight major producers of the monomer will add about 3.3 billion lb to capacity over next three years

Bruce F. Greek, C&EN Houston

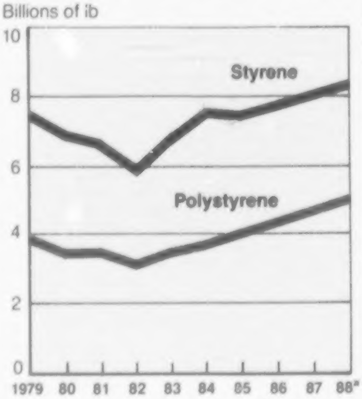
Utilization of all styrene plant capacity, a binge of new plant construction, and expansions of existing plants are enlivening the status of this mature petrochemical. Exports of styrene continue to be strong this year, with prices from sales to foreign markets more than doubling. Imports of styrene also have soared as efforts to meet fast-rising U.S. demand have pushed prices up strongly, although not to the high levels of spot export prices.

Styrene production this year could reach 8.4 billion lb, almost all the total U.S. capacity of about 8.5 billion lb. U.S. demand for styrene to make derivatives such as the various polymers and copolymers is growing rapidly compared with growth over the past decade. Nevertheless, styrene demand is growing more slowly than that for other basic monomers, such as some of the olefins. With output limited by capacity, further growth in styrene production is expected to be minimal, restricted to levels that can be achieved through debottlenecking of mostly old plants, until at least part of the new capacity is completed.

The binge of capacity expansions announced so far this year will add at least 3.3 billion lb over the next three years. The expansions announced by four of the eight major producers of styrene could add 39% to capacity by the end of 1991. Such potential production growth has not happened since 1983 and 1984, when styrene output was bouncing back from the 1982 recession, at year-to-year growth rates of 15% and 13%, respectively.

Restarting styrene plants that are shut down also could add capacity. Among shuttered plants, only Arco Chemical's plant at Monaca, Pa., has been restarted. That plant was shut down for a relatively short time (only since early 1986), so it could be brought back at reasonable cost. The large increases in selling prices during 1988 might provide incentives to restart a few shutdown units, but costs to restart other styrene plants closed for longer periods would be excessive, say industry sources. Such costs might not be made up before new capacity would come on stream and added competition would reduce current high returns on investment. Sources expect, therefore, that additional styrene production will have to come from new units with updated technology and from limited debottlenecking.

Both styrene, polystyrene output are growing slowly



a C&EN estimate. **Sources:** U.S. International Trade Commission, Committee on Resin Statistics of the Society of the Plastics Industry

Some industry sources doubt that all the additional announced styrene capacity will be built as scheduled. Some units have 1991 startup dates. Construction of styrene plants can be completed faster than other major plants such as steam crackers. For example, Chevron Chemical expects construction to begin on an

Capacity to make styrene will rise substantially

Millions of lb per year	Mid-1988 operating nameplate capacity	Capacity additions and remarks
Amoco Chemicals, Texas City, Tex.	750	
Arco Chemical, Monaca, Pa.	210	Restarted as of March 1988
Arco Chemical, Channelview, Tex.	1310	Studies under way on expansion to 2.31 billion lb
Chevron Chemical, St. James, La.	600	Expanding to 1.5 billion lb by 1990
Cos-Mar, Carville, La.	1500	Expanding to 1.9 billion lb by early 1990
Dow Chemical, Freeport, Tex.	1300	Considering 1 billion lb expansion by 1991-92
El Paso Products, Odessa, Tex.	320	
Huntsman Chemical[a], Bayport, Tex.	1000	
Sterling Chemical, Texas City, Tex.	1500	
TOTAL	**8490**	**Total potential capacity additions 3.3 billion lb**

a Operated by Hoechst Celanese

Rising styrene imports lower trade balance

Millions of lb	Exports	Imports	Trade balance
1979	961	38	923
1980	1205	51	1154
1981	1149	28	1121
1982	1025	21	1004
1983	1077	74	1003
1984	1170	102	1068
1985	1330	209	1121
1986	1307	319	988
1987	1130	425	705
1988[a]	1100	550	550

a C&EN estimate. **Source:** Department of Commerce

expansion of its St. James, La., plant in the first quarter of 1989, and to be completed in 1990.

Other major expansions are well into planning stages. Cos-Mar, a joint venture of Fina Oil & Chemical and Borg-Warner, will add 400 million lb of capacity by early 1990. By 1991–92, Arco Chemical will add 1 billion lb of capacity at Channelview, Tex., with 400 million lb of propylene oxide as coproduct. Dow Chemical also is planning to add 1 billion lb of capacity to its Freeport, Tex., plant.

Additional styrene capacity is being added or planned in many other countries. In Canada, for example, Polysar is restarting a 200 million lb-per-year unit at Sarnia, Ontario, with full operation slated by the end of the first quarter of 1989. Most of the production will be marketed in the U.S., Polysar says.

These expansions throughout the world are expected to reduce further net exports of styrene by U.S. producers. For nearly a decade, U.S. styrene exports have hovered around 1 billion lb annually, with imports a tenth (or less) of exports. Imports began to rise rapidly in 1985 as exports declined. This year, the trade balance is forecast at about 550 million lb, less than half of the trade balance three years ago.

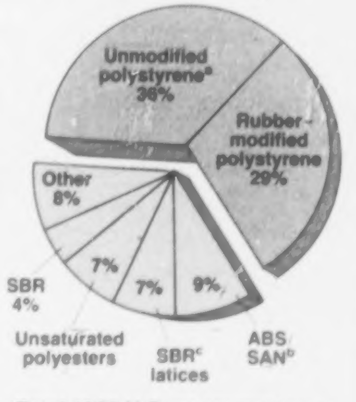
Growth in styrene imports and the decline in exports stem partly from increased demand in the U.S. Some of the increased styrene demand, however, will become exports as derivatives. Growth in exports of polystyrene, for example, has been rapid in the past three years. Outlook for export growth of styrene derivatives, longer term, is uncertain because of capacity growth in derivatives outside the U.S.

Vagaries of export markets for styrene have brought unusual price variations. Spot export prices for styrene reached about 85 cents per lb earlier this year but have dropped back below 60 cents per lb. The average export price during 1987 was 38.2 cents per lb, according to Department of Commerce data. For January through July 1988, the average export price of styrene was 52.4 cents per lb. The current contract price for sales in the U.S. is about 47 cents per lb.

With exports taking about 13% of U.S. styrene output this year, down slightly from last year's share, and with imports, largely from Canada, equal to about half of exports, U.S. consumption of styrene this year will be about 7.9 billion lb. Almost all of that styrene will go into polymers.

Polystyrene dominates consumption of styrene, requiring about 65% of total use. Unmodified polystyrene takes more than a third of consumption and includes two general categories—clear and expandable beads. The clear polystyrene often has additives and pigments in it and is fabricated by various molding and extrusion methods to make a wide variety of consumer products such as packaging items, housewares, and toys. Expandable beads are used in making foamed plastic items, largely used in some kind of packaging. Expandable beads account for about 11% of polystyrene sales and captive use, according to reports by the Committee on Resin Statistics of the Society of the Plastics Industry. Demand for these polymers has been growing faster than demand for the balance of polystyrenes, rubber-modified polystyrenes.

Polystyrene takes about two thirds of styrene use



Total 1988 U.S. consumption = 7.9 billion lb

a Includes expandable beads. b Acrylonitrile-butadiene-styrene, styrene-acrylonitrile. c Styrene-butadiene rubber. **Source:** C&EN estimates

Rubber-modified polystyrenes contain varying amounts of polybutadiene rubber, depending on the degree of impact resistance desired in the polymer. Most rubber-modified polystyrenes are molded or extruded to make nondisposables such as components of furniture, appliances, autos, toys, sporting goods, and other consumer items.

Copolymers of styrene with acrylonitrile and butadiene are a distant second as a market for styrene, at less than 10% of total use. Acrylonitrile-butadiene-styrene (ABS) resins account for more than 85% of this use, growth for which is forecast to be relatively low because of competition from other resins in many uses of ABS.

Copolymers of styrene and butadiene form another market category. Latices—often carboxylated—go largely into carpet backing and paper and textile coatings. Markets for these materials are growing at rates about equal to those for all polystyrenes.

Styrene-butadiene rubber (SBR) once dominated styrene consumption, but faster-rising demand for polystyrene long ago overcame SBR as the leader. Despite a modest increase in production expected in 1988, SBR will require less than 5% of U.S. styrene output.

Other important uses of styrene—unsaturated polyester resins and numerous other polymers—account for the rest of styrene consumption. Some of these smaller-volume resins are growing at rates above 5% annually, but their total consumption is so small that they will have minor impact on styrene demand for quite some time. □